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

June 2017

Volume 1: Facility

Budget Information, Response to Recommendations, Organizational Structure, Development Milestones, R&D, and Facility Input

Volume 1

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

AB – Authorization Basis
ABBIX – Advanced Beamline for Biological Investigations with X-rays
ABM – Authorization Basis Manager
AC – Alternating Current
AD – Accelerator Division
ADE-DOT – Acoustic Droplet Ejection-Droplet on Tape
AI – Active Orbit Interlock
ALS – Advanced Light Source
ALS – Amyotrophic lateral sclerosis
AMX – Highly Automated Macromolecular Crystallography
API – Application Programming Interface
APS – Advanced Photon Source
AP-XPS – Ambient Pressure Photo Emission Spectroscopy
ARI – ARPES and RIX Nano-Imaging
ARPES – Angle-Resolved Photoemission System
ARR – Accelerator Readiness Review
ASCR – Advanced Scientific Computing Research
ASE – Accelerator Safety Envelope
ASIC – Application-Specific Integrated Circuit
BAT – Beamline Advisory Team
BDN – Beamlines Developed by NSLS-II
BDP – Beamline Development Proposals
BER – Basic Energy Research
BES – Basic Energy Science
BL – Beamline
BM – Bending Magnet
BMM – Materials Measurement
BNL – Brookhaven National Laboratory
BPM – Beam Position Monitors
CAA – Cerebral Amyloid Angiopathy
CAD – Collider Accelerator Department
CCD – Charge Coupled Device
CD – Conceptual Design
CDI – Coherent Diffraction Imaging
CDW – Collimator Dispersing Wavelength
CFM-CSIC – Spanish Science Foundation
CFN – Center for Functional Nanomaterials
CHX – Coherent Hard X-ray Scattering
CMPMSD – Condensed Matter Physics Material Science Department
CMS – Complex Materials Scattering
CNR-IMEM
COMPRES
CSI – Computer Science Initiative
CSIRO - Center for Functional Nanomaterials Chemistry Condensed Matter Physics & Materials Science and Industrial Research Organization
CSS – Control System Studies
CSX – Coherent Soft X-ray Scattering
CXS – Coherent X-ray Scattering
CWRU – Case Western Reserve University
DAC – Digital to Analog Converter
DAMA – Data Acquisition, Management and Analysis
DBA – Double Bend Achromatic
DC – Direct Current
DEI – Diffraction Enhanced Image
DFG – German Research Foundation
DI – Deionized
DIPC – Donostia International Physics Centre
DOE – Department of Energy
DPC – Differential Phase Contrast
DTBLOC – Driving Terms Based Linear Optics Calibration
DW – Damping Wiggler
ECR – Extraordinary Construction Rate
EDP – Electron Density Profile
EE – Electrical Engineering
EEG – Electrical Engineering Group
ePDF – Electron Pair Distribution Function
EPICS – Experimental Physics and Industrial Control System
EPS – Equipment Protection System
EPU – Elliptically Polarized Undulators
ESF – European Science Foundation
ES&H (ESH) – Environmental Safety & Health
ESH&Q (ESHQ) – Environmental Safety, Health & Quality
ESM – Electron Spectro-Microscopy
ESR – Experimental Safety Review
ESRF – European Synchrotron Research Facility
EU – Energy & Utilities Division
EXAFS – Extended X-ray Absorption Fine Structure
FDR – Formal Design Review
FE – Front end
FEA – Finite Element Analysis
FEL – Free Electron Laser
FIS – Frontier Synchrotron Infrared Spectroscopy
FMX – Frontier Microfocusing Macromolecular Crystallography
F&O – Facility and Operations
FOFB – Fast Orbit Feedback
FTE – Full Time Equivalent
FXI – Full-field X-ray Imaging
FY – Fiscal Year
GHS – Gas Handling System
GISAXS – Grazing Incidence Small Angle X-ray Scattering

GIWAXS – Grazing Incidence Wide Angle X-ray Scattering
GPU – Graphical Processing Unit
GU – General User
GUI – Graphical User Interfaces
HEX – High Energy X-ray Scattering
HEXID – spectroscopic imaging detector
HFIR – High Flux Isotope Reactor
HGHG – High Gain Harmonic Generation
HMI – Human Interface
HPC – High Performance Components
HR – Human Resources
HQ – Headquarters
hrs – Hours
HTSC – High Temperature Superconductors
HVAC – Heating, Ventilating, and Air Conditioning
HXN – Hard X-ray Nanoprobe
IAEA - International Atomic Energy Agency
ICA – Independent Component Analysis
ID – Insertion Device
IEPD – Instrument Execution Plan Development
INF – Infra-red Spectrometer with nanoscale resolution
IO – Instrumentation Division
IR – Infra-Red
IRR – Instrument Readiness Review
ISM – Integrated Safety Management
ISR – Integrated In-Situ & Resonant X-ray Studies
ISS – Inner Shell Spectroscopy
IT – Information Technology
IVU – In-Vacuum Undulators
IXS – Inelastic X-ray Scattering
J-PLS – Jump start Polymer & Liquid Scattering
KB – Kirkpatrick-Baez
LARS – Laboratory Analysis of Returned Samples
LBT – Lanthanide-binding Tags
LCLS – Linac Coherent Light Source
LDRD Laboratory Directed Research & Development
LEEM – Low-Energy Beam Transport
LINAC – Linear Accelerator
LIX – Life Sciences X-ray Scattering
LOCO – Linear Optics from Closed Orbits
LOTO – Lock Out Tag Out
LSBR - Life Science Biomedical Technology Research
LT – National Synchrotron Light Source II Project
MBE – Molecular Beam Epitaxy
MCR – Main Control Room
MD – Molecular Dynamics
MED – Modulation Enhanced Diffraction
MEG – Mechanical Engineering Group
MEMS – Micro Electro Mechanical Systems
MET – Magnetospectroscopy, Ellipsometry & Time-Resolved Optical Spectroscopies
MIT – Massachusetts Institute of Technology
MLL – Multilayer Laue Lens
Mo – Master Oscillator
MOF – Metal Organic Frameworks
M&S – Material & Supply
MS&T – Material, Supplies & Travel
MtbFtsZ – Mycobacterium Tuberculosis Filamenting temperature-sensitive mutant Z
MX – Macromolecular Crystallography
NASA – National Aeronautics and Space Administration
NaV – Voltage gated sodium channels
NC - nanocrystal
nC – nano-Coulomb, a measure of electric charge
NEXAFS – Near-edge x-ray absorption fine structure
NEXT – NSLS-II Experimental Tools
NIGMS - Center for Functional Nanomaterials Chemistry Condensed Matter Physics & Materials of General Medical Sciences
NIH – National Institutes of Health
NIST - Center for Functional Nanomaterials Chemistry Condensed Matter Physics & Materials Institute of Standards and Technology
NMR – Nuclear Magnetic Resonance
NNSA – National Nuclear Security Administration
NP - nanoparticles
NPB – NSLS-II Partner Beamlines
NSF – National Science Foundation
NSF-EAR – National Science Foundation, Division of Earth Sciences
NSF-GEO – National Science Foundation, Directorate for Geosciences
NSLS – National Synchrotron Light Source
NSLS-II – National Synchrotron Light Source II
NYSBC – New York Structural Biology Consortium
NYX – Biological Microdiffraction Facility
ODH – Oxygen Deficiency Hazard
ORR Oxygen Reduction Reaction
OSCARS – Open Source Code for Advanced Radiation Simulation
PaNSig – Photon and Neutron Special Interest Group
PDB – Protein Data Bank
PDF – Pair Distribution Function
PEEM – Photo Electron Emission Microscopy
PLC – Programmable Logic Controller
PLS – Polymer Liquid Studies/Scattering
PRP – Proposal Review Panel
PS – Power Supplies
ps – pico-second
PPS – Personal Protection System
PS – Photon Science Division
PSI – Paul Scheurrer Institute
PS-II – Photosystem II

PU – Partner User
PV – Process Variable
PW – Pole Wiggler
QA – Quality Assurance
QAS – Quick X-ray Absorption and Scattering
QIX – Quick Inelastic X-ray
QPSI – Quantitative Plant Science Initiative
R&D – Research and Development
REXS – Resonant Elastic X-ray Scattering
RF – Radio Frequency
RIS4E – Remote In-Situ & Synchrotron Studies for Science & Exploration
RIXS – Resonant Inelastic X-ray Scattering
RMS – root mean square
ROT – Repressor of Toxin
RP – Retinitis Pigmentosa
SAC – Science Advisory Committee
SAD – Safety Assessment Document
SAGU – Segmented Adaptive-Gap Undulator
SAXS – Small Angle X-ray Scattering
SBIR – Small Business Innovation Research
SC – Super Conducting
SCES – Strongly Correlated Electron Systems
SCOTS – Software Configurable Optical Test Stations
SDCC – Scientific Data and Computing Center
SDD – Silicon Drift Detector
SEC – Size Exclusion Chromatography
SIX – Soft Inelastic X-ray Scattering
SLA – Service Level Agreement
SMF- Spectro Microscopy Facility
SMI – Soft Matter Interfaces
SNS – Spallation Neutron Source
SPI – Single Particle Imaging
SRX – Submicron Resolution X-ray Spectroscopy
SRW – Synchrotron Radiation Workshop
SSERVI – Solar System Exploration Virtual Institute
SST– Spectroscopy Soft & Tender
STXM – Soft X-ray Transmission X-ray Microscope
TEM – Transmission Electron Tomography
TES – Tender Energy X-ray Absorption Spectroscopy
THz – Terra Hertz
TLD – Thermoluminescent Dosimeter
TSP – Titanium Sublimation Pump
TXM – Transmission X-ray Microscope
UCNC – Upconverting Nano-Crystals
UEC – Users' Executive Committee
UED – Ultra-fast Electron Diffraction
UPS – Uninterruptible Power Supply
UV – Ultra Violet
VIPIC – Vertical Integrated Pixel Imaging Chip
vs - versus
WAXS – Wide Angle X-ray Scattering
WBS - Work Breakdown Structure
WFO – Work For Others
XAFS - X-ray Absorption Fine Structure
XANES – X-ray Absorption Near-Edge Structure
XAS – X-ray Absorption Spectroscopy
X-FELS – X-ray Free Electron Lasers
XFM – X-ray Fluorescence Microprobe
XFN – X-ray Fluorescence Nanoprobe
XFP- X-ray Footprinting
XPCS – X-ray Photon Correlation Spectroscopy
X-PEEM - X-ray Photo Emission Electron Microscope
XPD – X-ray Powder Diffraction
XPS - x-ray photoelectron spectroscopy
XR – X-ray Reflectivity
XRD – X-ray Diffracation
XRF – X-ray Fluorescence
YTD – Year to Date

1. Facility

1.i Brief Description of the Facility

The National Synchrotron Light Source II (NSLS-II) is a recently commissioned, world-class user facility for carrying out scientific research using synchrotron radiation. The X-ray ring is designed to operate at 3.0 GeV and a current of 500 mA. At the time of writing, it is operating at 300 mA in top-off mode, providing photon beams of ultra-high brightness and flux with exceptional stability. It has capacity for approximately 60 beamlines. When fully built out it is expected to service over 4000 unique users a year. As of May 2017, there are 19 beamlines in operation or commissioning and a further 9 under construction. Examples include a hard x-ray nanoprobe with world-leading spatial resolution in a user instrument and hard and soft x-ray coherent scattering beamlines with world-leading coherent flux in their respective energy ranges. The suite of beamlines provides the capability to characterize material properties and functions with nanoscale resolution and exquisite sensitivity. The facility features strong partnerships with BNL's Center for Functional Nanomaterials and other external institutions to enable additional capabilities for the user program. The strategic plan for the facility identifies three areas of focus: Emergent behavior and complexity, in-situ and in-operando science, and multiscale structures and functions, together with four cross-cutting areas to enable these themes: accelerator science and technology; advanced x-ray technology; multimodal sample environments; and data driven science. A particular emphasis is on fueling major advances in materials that will enable new energy technologies – such as next generation catalysts and advanced electrical storage systems.

1.ii Recommendations from the 2015 operating budget review, and facility's actions to address the recommendations

Below we outline the changes that have been made in response to the recommendations made following the June 2015 operations budget review. This represents an update to the report submitted in February 2016. This latter report is included for reference on the review website.

Recommendation 1: *Fully transition the NSLS-II organization from a construction project to an efficient and effective facility operations organization. The tasks to achieve this goal include, but are not limited to, rebalancing the staff skill mix and transitioning the staff size to an appropriate level, transferring non-mission specific business operations to laboratory central services, and re-assessing the Environmental Safety & Health (ES&H)/Quality Assurance (QA) program to streamline its processes and retain a core ES&H/QA staff within the NSLS-II organization that reports directly to facility.*

Responding to this recommendation has been a continuous process as we evolve from an entirely construction focused organization to an operations dominated one. While there are still significant construction activities underway in FY17, this has been a declining fraction of what we do. In FY15, about 40% of the work costed of the NSLS-II organization was construction, it was 40% in FY16 and it will be about 30% of the work costed in FY17.

Some of the actions taken to date include:

- Following the June 2015 review, we reduced and rebalanced the accelerator operations, facility management and ESH&Q portions of the organization. In FY16, this totaled an overall reduction of 13% relative to the June 2015 FY16 budget numbers, and below the numbers suggested by BES in a January 2016 analysis. We have maintained these numbers in the FY17 budget.
- Reduced FY16 accelerator operations by 15 FTEs relative to the June 2015 review, including a reduction of 4 accelerator physicists, while at the same time increasing the preventive maintenance and spares program. This has been maintained in FY17. In FY17 there are 10 fewer accelerator physics in the organization as compared to the start of operations in FY15.
- Reorganized the controls program, moving it from the Accelerator Division to the Photon Science Division to more accurately reflect its major responsibilities.
- Moved certain ESH responsibilities to the central ES&H organization
- Streamlined the IRR and engineering processes.
- Launched and completed an initiative to address overall proceduralization of the NSLS-II organization, reducing the number of procedures from approximately 350 to 150when the effort is complete. This initiative pushes more decision making authority and responsibility for everyday work practices down towards the technical level within the organization utilizing process description, program description and work instructions for much of the work of the facility and reserving procedures for those activities that involve safety critical activities. We are also streamlining and relaunching the document center to ensure documents and records are well maintained and easy to find.
- Moved the ESH&Q manager to report directly to the NSLS-II Facility Director, effective March 20, 2016. Other ESH functions are provided under SLA agreements with the central organization as needed.

Recommendation 2: *Establish clear operational priorities across the NSLS-II organization to ensure excellent machine performance and scientific output. These priorities should include, but not be limited to, conducting preventative maintenance, maintaining a sufficient pool of critical spare parts and equipment, and delivering maximum operating hours, 5,000 hours or more per year, reliably to users by FY2018*

As a facility we have established clear operational priorities that have been communicated throughout the organization and which inform decisions at all levels, but most especially in terms of setting budget priorities. The high level priorities are, in order;

1) Operate the accelerator at > 95% reliability. Increase the performance (current, stability, emittance) consistent with maintaining good reliability and funding levels.
2) Operate the existing beamlines at a lean, efficient level.
3) Develop new beamlines. Within the construction portfolios, priorities will be set as determined by impact on user community, agreements with Partner institutions, and funding levels.
4) Carry out development activities including mission relevant R&D and development of existing sub systems to improve performance.

Underlying all these priorities is the commitment to maintain operational excellence across the organization.

Reflecting these priorities, subsequent to the June 2015 review we have taken a number of actions, in regard to the accelerator performance. These are discussed below.

In February 2016 we held a Reliability Workshop to assess the effectiveness of the programs within NSLS-II. These were also the subject of discussion sessions at the High-Brightness Synchrotron Light Source Workshop held at NSLS-II in April 2017. As a result of these and related activities, we have established a robust process for tracking causes of downtime, compiling statistics on causes of faults and length of downtime, sub-system by sub-system. These have improved our reliability program.

We have established a detailed spares list. The spares are categorized into three categories; items for which failure would cause the machine to shutdown (category 1), items that would reduce performance (category 2) and items that could be fixed at the next maintenance period (category 3). Based on factors such as cost, lead time and likelihood of failure, decisions are then made on which spares to buy. The table below reflects the current status of the spares program as of April 2017.

Spares ($M)	1. Halt ops immediately	2. Impede performance	3. Can wait until break in ops	Total
In Stock	11.66	10.94	4.05	26.64
Not in stock	2.65	0.61	3.98	7.25
Total	14.31	11.55	8.03	33.89

Table 1.ii.1: Estimated Value of Spares for Accelerator Operations

To accommodate this spares program, we increased the spares budget by $300 K in FY16, relative to the original budget presented in the June 2015 review and in FY17, we will spend a total of $6.2M on materials including consumables and spares (both replacement spares that have been used and new spares), emphasizing the spares that have a high impact on reliability.

For example, as part of this program, we initiated the fabrication of the 3rd SC RF cavity in FY16 and have continued this in FY17 on a technically limited schedule. This has been identified as one of the highest priority spares. Presently, failure of one of the two cavities operating in the storage ring would cause significant degradation in performance. In addition, a powered third cavity will be required to increase the operating current up to 500 mA. For these two reasons, this is a high priority item.

As a result of this focus on reliability we have seen a significant decrease in machine downtime over the course of the first two and a half years of operations. This is shown below in terms of total hours of downtime. Over the same period, the reliability has increased to more than 96% for FY17 YTD.

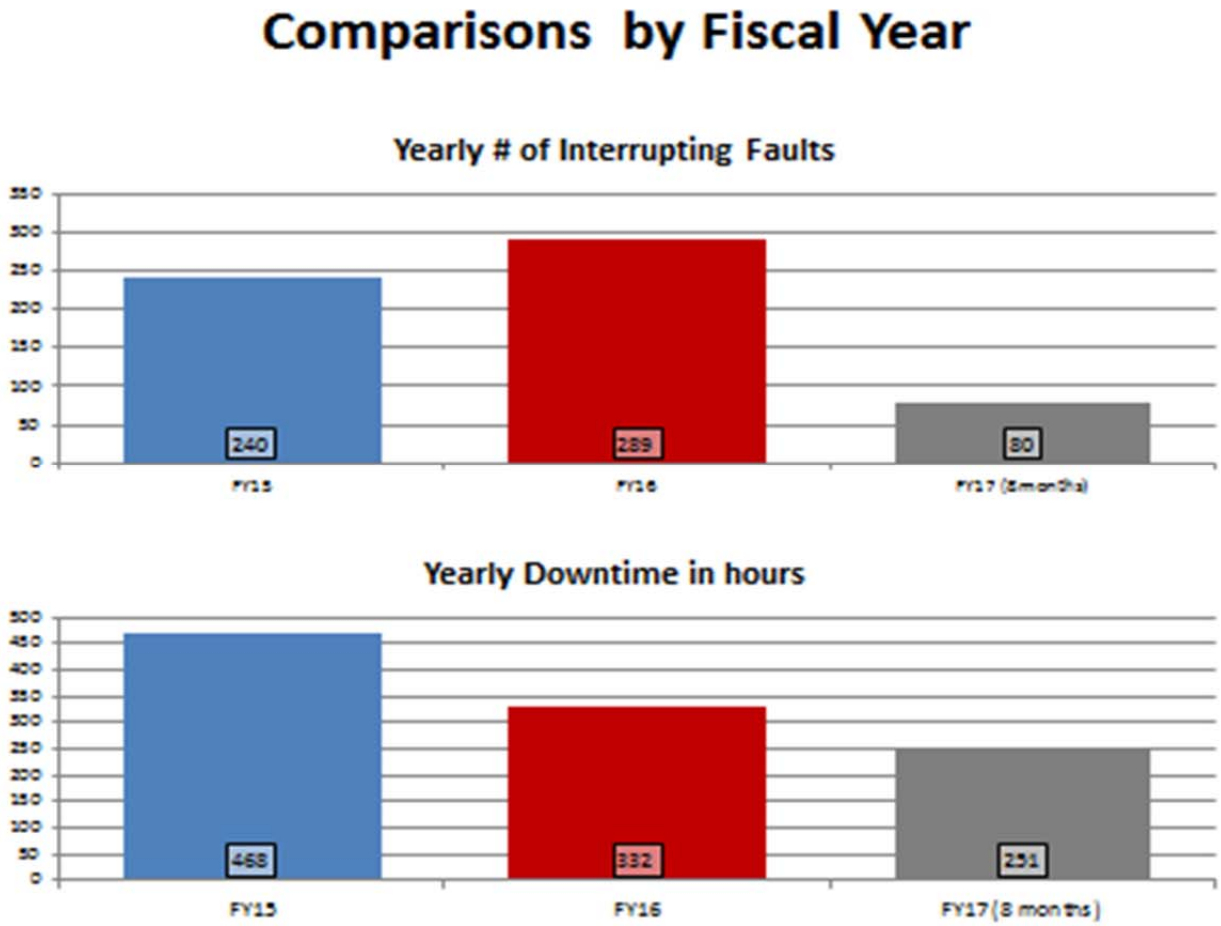

Figure 1.ii.1: Yearly # of Interrupting Faults and Yearly Downtime in Hours

In regard to operating hours, following our experience of front end and beamline commissioning in FY15 and FY16, we have reduced the time for these activities for the new beamlines going forward. Nevertheless, this remains a major draw on machine time. In FY18, we have budgeted 520 hours for this activity. This includes commissioning of the XFM and QAS 3-pole wigglers and associated front ends, and low current operations for radiation surveys of these beamlines to certify them up to full current operations. It also includes the commissioning of IDs and front ends for the SST-1 and SST-2 beamlines and the low current operations for the radiation surveys for these beamlines and the same for the FXI and FIS/MET beamlines. In FY17, we were averaging 6 shifts (48 hours) of beam for a bending magnet and 16 shifts (128 hours) for an insertion device beamline. If the new beamlines take the same amount of time, then that would be a total of 528 hours of commissioning required, slightly over our budget. In addition, this beamline commissioning time is also required for alignment of IDs for maximizing spectral harmonics and optimization of feed-forward tables on existing beamlines. Therefore at the time of writing, we feel we cannot reduce the budgeted time further. Nevertheless we remain committed to providing as many user operations hours as possible and we will revisit this question towards the end of FY17 when we have a clearer picture of the activities required in FY18, with a view to increasing the number of user operations hours.

In addition we have sought, and received, permission to recertify personnel protection systems' interlocks on an annual basis, rather than on a six monthly basis. This has reduced the time needed to perform such activities per beamline and we have been able to hold the time for maintenance and certification constant even as more beamlines have become operational. Further, we have reduced accelerator studies time. This time is used to study the behavior of the machine at high currents - to support the goal of increasing the operating current, to develop and understand low emittance running and to improve beam stability.

As a result of these actions, we have increased the scheduled user operations hours to 4500 in FY17, 4750 in FY18 and 5000 in FY19, as shown below. As noted above because of the remaining commissioning activities in FY18 we were not able to commit to the goal of 5000 user hours in FY18 at the time of writing. Nevertheless, we will revisit this question towards the end of FY17 and increase the operating hours if at all possible.

	NSLS-II			
	FY16	FY17	FY18	FY19
Operations (hours)	3718	4500	4750	5000
Studies (hours)	1713	872	850	850
Maintenance and certification (hours)	594	440	440	440
Shutdown (hours)	2825	2224	2200	2200
ID, FE, BL Commissioning (hours)		724	520	270
Reliability, %	90	95	95	95
Operating Current: Start/End (mA)	200/250	250/300	300/400	400

Table 1.ii.2: Accelerator Operation Hours, broken out by user operations, studies, maintenance and certification, shutdown and commissioning activities. In FY16, commissioning activities are included in the total.

Recommendation 3: *Use operating funds to accelerate beamline development. Starting in FY2016 and going forward through at least FY2019, based on the current FY2016 funding level, NSLS-II should have sufficient operating funds to initiate the development of one new world class beamline each year in addition to the BDN portfolio.*

Having made tough choices in the Accelerator, Facility and ESH&Q portions of the operating budget, bringing them to below the levels of the Jan. 2016 BES analysis, we have freed up significant budget for beamline operations and development in FY16 and beyond. This has been sufficient to operate the existing beamlines, to continue to build all the BDN and NPB beamlines and to start the development of new state-of-art beamlines in FY16 and continuing in FY17.

Activities on new beamlines in FY16 and FY17 centered on the work of the Instrument Execution Plan Development (IEPD) task force which was charged with developing 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, a down-selection to solicited Beamline Development Proposals (BDPs) that were then externally

reviewed and presented to our Science Advisory Committee. This process resulted in six approved NSLS-II beamline development proposals. The IEPD taskforce was charged to:

1. Clarify the scope of each instrument engagement that could be constructed
2. Evaluate any R&D program that might be needed to deliver the intended scope
3. Develop initial cost estimates (ranges) for the described scope (including R&D program)
4. Propose an initial technically limited schedule

The task force delivered its final report in February 2017. This report is on the review website and in addition is discussed further in Volume 2b: Beamlines Capability Build-up Plan of the review documentation. The "engagements" are a two beamline sector for Soft X-ray Microscopy and spatially-resolved combined nanoRIXS/nanoARPES spectrometer (SMF/ARI), a beamline for Bragg coherent diffraction imaging (CDI), a side station for thin film polymer processing and liquid interface studies (PLS), a quick inelastic x-ray scattering instrument for studying chemical reactions in situ (QIX) and an STM-based infra-red spectrometer with nanoscale resolution (INF). In brief, the task force came up with the following cost and schedule estimates for the 5 engagements:

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 1.ii.3: Cost and Schedule Estimates for the five "engagements".

These estimates, while very preliminary, document the assumptions behind them and provide sufficient detail that funding for each of these engagements may now be sought from diverse funding sources.

During the course of the FY17 continuing resolution, these activities were placed in a "go-slow" mode, reflecting the uncertainty in the overall funding level for FY17 and the respective priorities of all activities within the operations budget. With the FY17 budget now clear, budget decisions have been made. NSLS-II will pursue the CDI beamline from operations funds and at the time of writing is concluding a search for the lead beamline scientist to lead this effort. In addition, we have begun an R&D program to study the principles of the ARI spectrometer, to determine if it will deliver the performance promised. This work will be carried out in close collaboration with

the ALS. Finally, it was decided to expend a relatively small amount of effort to refurbish a liquid spectrometer that had been running at 9-ID at the APS and place it at the SMI beamline. This will give the PLS user community some capability, albeit at reduced capacity since it will not be able to run independently of SMI. It is intended to help build the case for funding the PLS beamline from an external sponsor such as the Department of Commerce. This effort is denoted J-PLS for Jump-start PLS. However, only the CDI beamline will be pursued under operations funding. The others will not be pursued further until additional funding has been identified. We will not expend resources to advance these concepts without an explicit reason to do so. The present activities will be carried out within the beamline construction group of NSLS-II. When a given project has reached the baseline point (i.e. equivalent to a "CD-2" in a formal DOE project) then the activities will be transferred to the appropriate portfolio to manage the cost, scope and schedule and to deliver the engagement into operations.

At the time of writing, budget uncertainty in FY18 and beyond is extreme and it is difficult to state with confidence what will be possible going forward. However, with the increasing number of beamlines coming into operations, we believe initiating a new beamline in each subsequent year with the intention to follow it through to completion on BES operating funds is not a possibility in any plausible funding scenario. To do so would incur large risks to the scientific productivity of the facility and would significantly damage the user community on the existing beamlines since it would likely require the support levels on the completed beamlines to be reduced to well below minimal levels for productive and safe full time operation of the beamlines.

Recommendation 4: *Re-evaluate the overhead rates applied to the NSLS-II operations budget.*

This was a concern raised due to the apparent increase in the overhead rates as seen in the data presented at the June 2015 operations review. In fact the overhead rates were held constant for the FY15-FY19 period in the materials for that review. The apparent increase was largely due to two factors:

First, the direct dollars were quoted in FY15 dollars and the escalation dollars included in the indirect costs. We recognized that this was a very confusing way to present the data and had the effect that it appeared that the overhead rates were increasing. This was corrected in the response provided in 2016 (see document on the review website).

Second, the portion of the operations budget that was funding beamline development (i.e. the BDN and NPB work) incurs the very favorable Extraordinary Construction Rate (ECR) negotiated with BNL for work started before CD-4 of the NSLS-II project. The ECR is 10.5% (and 0% for capital equipment and purchases over $2 M). As this work winds down and the work of the facility transitions from developing beamlines to operating them, then more of the operations funds get the regular burden. If one looks at the ratio of the total direct costs to total indirect costs, then this transition has the effect of appearing as if the overhead rate is increasing, even if the rates are constant. What is in fact changing is the relative mix of the different activities.

In the table below, we calculate the ratio of direct costs to indirect costs for the operations funds for FY15-17. In this calculation, space charges are included as an indirect cost. We note that we

have negotiated a very favorable deal with BNL such that we only pay space charges on the segments of the ring building occupied by beamlines in the General User program (and we "pay by the drink" for the remainder of the building). This means that the space charges increase as we bring more beamlines into operations. The direct costs here are salary, MS&T and power. We see that this ratio increases as the beamline development activities decrease and the space charges increase with time.

Also included in table 1.ii.4 is FY17 with the ECR activities taken out. This represents an approximation of what the effective overhead rate might be when all the ECR activities have finished.

Total	FY15 ($k)	FY16 ($k)	FY17 ($k)	FY17 with no BL Dev ($k)
Direct costs (salary, M&S, power)	56,113	64,295	78,696	59,528
Space Direct	5,338	5,563	6,000	6,000
Indirects	28,485	28,153	35,885	32,500
Overhead (Indirects + Space)	33,823	33,716	41,885	38,500
(Indirects+Space)/Direct	60.3%	52.4%	53.2%	64.7%

Table 1.ii.4: Effective overhead rate on BES funds for FY15-17

Please note: The effective rate is calculated as the sum of indirects and space, divided by the total direct costs. The effective rate changes from year to year depending on the relative mix of those beamline development activities which get burdened at the much lower Extraordinary Construction Rate (ECR) and other activities which get burdened at the regular BNL rates. The final column is a notional FY17 cost profile with all the ECR activities taken out.

Finally, we note that in FY19, the cost accounting standards will change at BNL. This is discussed in Volume 3, section 7.1 of the review documentation. The effect of this change is to bring BNL into compliance with DOE expectations and to use a value added base in its overhead methodology. Relative to the present overhead rate scheme, the effect will be to reduce overhead rates on materials and supplies, to reduce space rates and to increase the cost of labor. The rates will be chosen to be cost neutral across BNL, that is the net overhead recovery will be the same as currently.

1.iii Facility Budget Information

a. Provide a fiscal year (FY) 15, and FY16 budget table of DOE-BES funds for operating, Accelerator Improvement Project (AIP), and capital equipment as they were allocated for salary, non-salary, and power.

Provided below is a summary table of the FY15 and FY16 NSLS-II DOE BES funds.

ACTUALS (K$)

	FY15 ACTUALS				FY16 ACTUALS			
	LABOR	NON LABOR	ELEC. POWER	TOTALS	LABOR	NON LABOR	ELEC. POWER	TOTALS
NSLS II								
Operations	$ 57,222.3	$ 26,084.2	$ 2,262.8	**$ 85,569.4**	$ 53,778.2	$ 24,713.8	$ 1,655.6	**$ 80,147.6**
AIP	$ -	$ -	$ -	**$ -**	$ -	$ -	$ -	**$ -**
Capital Fabrication	$ 2,489.4	$ 1,877.8	$ -	**$ 4,367.2**	$ 9,019.9	$ 8,843.8	$ -	**$ 17,863.6**
Total PS001	**$ 59,711.7**	**$ 27,962.1**	**$ 2,262.8**	**$ 89,936.5**	**$ 62,798.1**	**$ 33,557.5**	**$ 1,655.6**	**$ 98,011.3**

Note: Electric Power does not include the "Electric - Distributed" as a percent of labor.That amount is included in the overhead applied to labor.

Table 1.iii.1: FY15 & 16 Budget Table for DOE BES Funds.
Capital Fabrication include both capital fabrication projects and beamline development.

b. Provide a table summarizing the annual carryover of DOE-BES funds for FY15 and FY16.

Provided below is a summary table of the annual carryover of DOE-BES funds for FY15 and FY16.

CARRY OVER

	FY15 K$				FY16 K$			
	Commits*	Dedicated Funds	Uncommitted	Total Carryover	Commits*	Dedicated Funds	Uncommitted	Total Carryover
Operations	2,519	3,867	10,084	16,469	5,481	1,277	19,028	25,786
AIP	0	0	0	0	0	0	0	0
Capital Fabrication	6,469	0	-2,023	4,445	6,003	633	121	6,757
	8,987	**3,867**	**8,060**	**20,915**	**11,484**	**1,910**	**19,149**	**32,543**

* Commits are burdened values

Table 1.iii.2: FY15 & 16 Annual Carryover DOE-BES Funds.

Please note: at the end of FY15, capital funds were awaiting the transfer of $3M from dedicated to capital funds. The $3M are in dedicated funds in FY15.

In the above table, the total carryover is reported for FY15 and FY16. At NSLS-II, we distinguish carryover into three categories. These are "committed", i.e. funds against which a requisition has been placed. These funds will be costed when the contract comes due. There are other funds for which we have firm plans in the out years. These include activities such as BDN and NPB for which there is a defined spending profile. In principle, these funds could be repurposed if required, but it would impact those programs. Finally, we have uncommitted. These are funds which can be allocated as the out year requires without impacting existing activities.

c. Provide a table showing all other FY15, and FY16 funding (e.g., Laboratory Directed Research and Development, Work for Others, Proprietary Research Cost Recovery, etc.) for facility-operated beamlines.

Provided below is a table showing all other FY15 and FY16 funding for facility-operated beamlines.

	Project	Description	PI	Funding Actual FY15 ($k)	Actual FY16 ($k)	Expected FY17 ($k)	Strategy
PD/LDRD #							
12-018	19069	Conical Slit for Probing Buried Micron or Sub-Micron Volumes for Dynamic Measurements of Heterogeneous	N. Bouet	15.9	0.0	0.0	b
12-023	19072	Femto-second X-ray Pulse Generation by Electron Beam Slicing	L. Yu	31.3	0.0	0.0	a
13-031	20200	Modulation Enhanced Diffraction: a new tool for powder diffraction and total scattering studies	E. Dooryhee	138.9	3.6	0.0	1
13-032	20215	Dev At-Wavlgnth Metrology Tools	M. Idir	268.0	24.9	0.0	b
13-033	20216	Multi Dim Imaging Data Analysis	W. Lee	283.3	28.2	0.0	d
13-034	20217	Atomic resolution Element Map	E. Nazaretski	169.9	8.7	0.0	b
13-015	20322	PD (Post Doc Interview Support)	K. Didie	0.0	2.0	0.0	NA
14-021	20662	In-Situ Investigation of the Strain Distribtuion in Next-Generation 3D Transistors Using X-Ray Nanodiffraction	H. Yan	181.3	100.1	0.0	2
15-038	21114	Segmented Adaptive-Gap Undulator with Different Period Lengths in Segments for Production of High Flux and Brightness Hard X-rays at NSLS-II	O. Tchoubar & C. Kitegi	340.8	365.9	0.0	a
15-031	21118	Inelastic X-Ray Scattering determination of the inter- and intra-particle dynamics of nanoparticle superlattices: key to the development of THz phononic crystals	A. Cunsolo	78.5	151.6	52.6	1
15-037	21120	In-situ microscopy investigation of complex manganese oxides for energy storage	Y. Chu	250.0	216.1	97.7	2
15-034	21121	Searching and sorting haystacks	S. McSweeney	53.1	210.7	133.6	3
16-006	21689	Serial Micro Crystallography at Full Flux	M. Fuchs	0.0	139.3	156.0	3
16-007	21690	3D Ptychography imaging without rotation using highly convergent X-ray beam	X. Huang	0.0	110.2	197.4	b
16-010	21691	100fs single-shot electron beam slicing technology towards ultra-fast imaging	L. Yu, Y. Zhu, T. Shaftan, F. Willeke	0.0	352.0	332.0	a
	21952	17005 Post Doc Lab Support	K. Didie	78.2	68.5	84.9	NA
17-015	22367	NSLS II High Brightness Studies	E. Blum	0.0	0.0	276.0	a
17-016	22368	Diffraction limited and wavefront preserving reflective optics development	M. Idir	0.0	0.0	189.0	b
17-017	22369	Development of compact, high efficiency nanofocusing optics for hard x-ray nano-imaging	E. Nazaretski	0.0	0.0	94.6	b
		Total LDRD and PD		**1,889.2**	**1,781.8**	**1,613.8**	
SPP's, Partner, Proprietary & Other Funding							
BER	19168	LSBR	S. McSweeney	3,898.2	2,500.0	2,554.0	
OFA	20907	NIH-LSBR P41	S. McSweeney	2,480.9	3,837.2	3,356.2	
SBIR	84112	Accustrata	N. Bouet	0.0	0.0	8.0	
Partner Beamlines							
OFA	20472	BMM/SST - NIST	E. Johnson	0.0	7,605.0	0.0	
NFA	87371	XFP - CASE WESTERN	A. Broadbent	1,400.0	600.0	115.7	
NFA	87390	NYX - NYSBC	H. Robinson	1,000.0	948.0	35.0	
NFA	87356	HEX -NYS	E. Johnson	0.0	0.0	3,350.0	
PROPRIETARY RESEARCH							
	89304	PRT-NeoProteomics	S. McSweeney	0.0	0.0	3.3	
	89305	PRT-Melinta	S. McSweeney	0.0	0.0	26.4	
	89312	PRT-Bristol Myers Squibb	S. McSweeney	0.0	0.0	6.6	
	89315	PRT-Pfizer, Inc.	S. McSweeney	0.0	0.0	8.2	
Other Funding							
BES	22021	Wavefront Preserving Mirrors	M. Idir	0.0	246.0	368.0	
BES	22022	Saw-Tooth and Kinoform Lenses	K. Evans-Lutterodt	0.0	150.0	150.0	
		Total SPP, Partner, Proprietary & Other Funding		**8,779.1**	**15,886.2**	**9,981.4**	
		Total Other Funding		**10,668.3**	**17,668.0**	**11,595.2**	

Table 1.iii.3: FY15 & 16 Other Funding Received

Please note: the table above reflects funding received in a given fiscal year, not costs, and is therefore different from table 1.iii.9 (section e). The column labeled "Strategy" indicates how a given LDRD supports our strategic plan. In particular, the strategic plan details the following areas of focus: (1) emergent behavior and complexity, (2) in-situ and in-operando science, and (3) multi-scale structures and functions. In addition there are four cross-cutting areas to enable these themes: (a) accelerator science and technology, (b) advanced x-ray technology, (c) multi-modal sample environments, and (d) data driven science.

d. Provide the following tables that (1) calculate labor multiplier based on $100,000 base salary; (2) Materials and Supplies (M&S) indirect rate based on $10,000 purchase; and (3) equipment indirect rate based on $500,000 purchase for FY2015-FY2-16. In addition, please provide tables which calculate labor multiplier based on $100,000 base salary and M&S indirect rate based on $10,000 purchase for a project (AIP, GPP, etc.).

(1) The following table provides the labor multipliers for FY15 & FY16.

FY2015 Operation Fund-Based on Y/E rates

Item	Base Applied	Based Amount	Rate	Cost	Published rate
Base Salary Cost				$ 100,000	
Paid absence					
Fringe	Base Salary		39.0%	$ 39,000	39.0%
Total Direct				$ 139,000	
Org Burden	Total Direct	$ 139,000	7.43%	$ 10,328	
Distributed Power	Total Direct	$ 139,000	0.85%	$ 1,182	
LDRD	Total Direct & org burden	$ 149,328	3.70%	$ 5,525	3.70%
Common Support G & A	Total Direct & org burden	$ 149,328	31.95%	$ 47,710	31.95%
Traditional G & A	Total Direct & org burden	$ 149,328	7.22%	$ 10,781	8.25%
Total Fully Burdened Cost				$ 214,526	
Labor Multiplier				2.14526	

FY2016 Operation Fund-Based on Y/E rates

Item	Base Applied	Based Amount	Rate	Cost	
Base Salary Cost				$ 100,000	
Paid absence					
Fringe	Base Salary		39.7%	$ 39,700	39.7%
Total Direct				$ 139,700	
Org Burden	Total Direct	$ 139,700	8.83%	$ 12,336	
Distributed Power	Total Direct	$ 139,700	1.20%	$ 1,676	
Common Support G & A	Total Direct & org burden	$ 152,036	32.35%	$ 49,183	32.35%
Traditional G & A	Total Direct & org burden	$ 152,036	7.38%	$ 11,220	8.25%
LDRD	Total Direct & org burden & OH	$ 214,116	2.30%	$ 4,925	2.30%
Total Fully Burdened Cost				$ 219,040	
Labor Multiplier				2.190403	

Note: Rates calculated in tables represent the rates at year end . The last published rates are provided for reference.

Table 1.iii.4: Labor Multipliers for FY15 & 16 based on a $100,000 salary

(2) The following table provides the material and supply (M&S) multipliers for FY15 & FY16.

FY2015 Operation Fund-Based on Y/E rates

Item	Base Applied	Based Amount	Rate	Cost	Published rate
M&S purchase				$ 10,000	
Org Burden			0.00%		
Material Burden	M&S Purchase	$ 10,000	7.50%	$ 750	7.5%
Lab Overhead	M&S Purchase & Matl Burden	$ 10,750	42.87%	$ 4,609	43.90%
Total Fully Burdened Cost				$ 15,359	
Total Indirect Rate				53.585%	

FY2016 Operation Fund-Based on Y/E rates

Item	Base Applied	Based Amount	Rate	Cost	
M&S purchase				$ 10,000	
Org Burden			0.00%		
Material Burden	M&S Purchase	$ 10,000	7.50%	$ 750	7.5%
Lab Overhead	M&S Purchase & Matl Burden	$ 10,750	39.73%	$ 4,271	40.60%
LDRD on Total cost	M&S Purchase, MB, overhead	$ 15,021	2.30%	$ 345	2.3%
Total Fully Burdened Cost				$ 15,366	
Total Indirect Rate				53.665%	

Note: Rates calculated in tables represent the rates at year end . The last published rates are provided for reference.

Table 1.iii.5: M&S Multipliers for FY15 & FY16 for a $10,000 purchase

(3) The following table provides the equipment multipliers for FY15 & FY16.

FY2015 Operation Fund

Item	Base Applied	Based Amount	Rate	Cost	Published rate
Equipment purchase				$ 500,000	
Org Burden			0.00%		
Material Burden	Equipment purchase	$ 500,000	7.50%	$ 37,500	7.5%
Lab Overhead	material burden	$ 37,500	42.87%	$ 16,076	43.90%
Total Fully Burdened Cost				$ 553,576	
Total Indirect Rate				10.715%	

FY2016 Operation Fund

Item	Base Applied	Based Amount	Rate	Cost	
Equipment purchase				$ 500,000	
Org Burden			0.00%		
Material Burden	Equipment purchase	$ 500,000	7.50%	$ 37,500	7.5%
Lab Overhead	material burden	$ 37,500	39.73%	$ 14,899	40.60%
LDRD on Total cost	equip, MB, overhead	$ 552,399	2.30%	$ 12,705	2.3%
Total Fully Burdened Cost				$ 565,104	
Total Indirect Rate				13.021%	

Assumes Capital Fabrication Project

Note: Rates calculated in tables represent the rates at year end . The last published rates are provided for reference.

Table 1.iii.6: Equipment Multipliers for FY15 & FY16 for a $500,000 purchase

The following table provides multipliers for labor, materials and supplies and equipment purchases for extraordinary rated projects for FY15 and FY16. Note AIP and GPP projects get the same rates as regular operations, i.e. as listed in the previous tables.

Project Labor (for FY15 & FY16 - NSLS II EC rate applied) *					**FY 2015**		**FY2016**
Item	Base Applied		Based Amount	Rate	Cost		
Base Salary Cost					$ 100,000		$ 100,000
Paid Absence							
Fringe	Base Salary			39%	$ 39,000	0.397	$ 39,700
Total Direct					$ 139,000		$ 139,700
Org Burden				0%	$ -	0%	$ -
Distributed Power				0%	$ -	0%	$ -
LDRD				0%	$ -	0%	$ -
Common Support G & A	Total Direct	$	139,000	6.5%	$ 9,035	6.5%	$ 9,081
Traditional G & A	Total Direct	$	139,000	4.0%	$ 5,560	4.0%	$ 5,588
Total Fully Burdened Cost					$ 153,595		$ 154,369
Labor Multiplier					$ 1.536		$ 1.544

Note: Fringe rate changed for FY16 hence the additional column.

Project M&S					
Item	Base Applied		Based Amount	Rate	Cost
M&S purchase (for FY15 & FY16 - NSLS II EC rate applied)					$ 10,000
Org Burden					
ALD Burden	M&S Purchase				$ -
Lab Overhead	M&S Purchase	$	10,000	10.5%	$ 1,050
Total Fully Burdened Cost					$ 11,050
Total Indirect Rate					10.50%

Equipment purchase (for FY15 & FY16 - NSLS II EC rate applied)					
Item	Base Applied		Based Amount	Rate	Cost
Equipment purchase					$ 500,000
Org Burden				0.00%	
Material Burden	Equipment purchase	$	500,000	0.00%	$ -
Lab Overhead	material burden	$	-	10.50%	$ -
Total Fully Burdened Cost					$ 500,000
Total Indirect Rate					0.000%

*The extraordinary construction rate was granted as an exception for NSLS-II, ABBIX, NEXT, and BDN projects. Under new cost accounting guidelines it is unlikely to be granted again in the future

Table 1.iii.7: Multipliers for Labor, Materials, and Supplies FY15 & FY16 for extraordinary construction rate (ECR) projects.

Please note: these rates are for the extraordinary construction rate granted to NSLS-II, ABBIX, NEXT, BDN and NPB projects. Under cost accounting guidelines, such rates will be much harder to get in the future and most projects will be charged at the regular overhead rates.

Table 1.iii.8 summarizes the total funding for each of FY15-17 including new budget authority (BA), uncommitted carry forward from the previous year and dedicated and committed carry forward from the previous year. It also shows operations costs for FY15-17 below broken out and into operations costs, cap/fab (construction) costs, commitments and dedicated funds carried forward into subsequent fiscal years and the uncommitted carry forward. FY15, 16 represent actual costs. FY17 is projected costs at the end of the fiscal year.

Operations Funds and Costs ($M)			
	Actual	**Actual**	**Expected**
	FY15	**FY16**	**FY17**
new BA (Budget Authority)	90.1	109.6	111.8
committed carryforward from previous FY (burdened)	4.1	9	11.5
dedicated funds carried forward from previous FY (unburdened)	0	3.9	1.9
Uncommitted carryforward from previous FY (unburdened)	16.7	8	19.1
Total Funds	**110.9**	**130.5**	**144.3**
Ops Costs	85.6	80.1	98.1
BL Build up costs	4.4	17.9	22.5
commitments into next FY (burdened)	9	11.5	4.2
dedicated funds carried forward into next FY (unburdened)	3.9	1.9	3.5
uncommitted carryforward into next FY (unburdened)	8	19.1	16
Total Cost, Commitments & Carryforward	**110.9**	**130.5**	**144.3**

Table 1.iii.8: Operations Funds & Costs for FY15-17

e. Operation Budget Details and Projections

FY2015-FY2016 Operation Budget Details and FY2017 Operation Budget Projections: Provide a table that breaks down all staff and their assignments [FTEs and budget allocations to each specific assignment]: facility management and business operation staff, accelerator staff; accelerator operations staff; engineers and technicians assigned to accelerator operations support; facility beamline scientists; facility beamline operational staff; engineers and technicians assigned to user support, control, and computing; clerical and administration, and Environmental, Safety & Health/Quality Assurance. Indicate personnel and budget allocation to each of these assignments under DOE/BES and other funding. Describe each staffing category in this table (types of staff included in each category and their activities).

In the table below, we provide the FY15-17 operations budget details. In particular, these are FY15, 16 actuals and for FY17, they are actuals through March 2016 and projections to the end of the fiscal year. The yellow coded rows represent R&D activities (materials and labor) and beamline development activities (materials and labor). These activities are included in the data above and broken out in these rows for clarity. Since they are already included above, these rows are "non-add" and don't contribute to the totals to avoid double counting. The labor and materials in this table are grouped by the area the work was done in, not the part of the organization that contributed to the labor. So for example, if staff from the Accelerator Division worked on beamline development, they are recorded in the "beamline operations" total, and in the beamline development "non-add" rows. The BES-SUF funding columns include BES operations funded work and BDN and NPB work. They do not include NSLS-I operations funded work, NSLS-II construction project or NEXT funded work. Other funding source work is operations work funded by others. This includes BER/NIH funding of beamline operations (LSBR grant), LDRD, proprietary work, SPP work, and the HEX project. It does not include ABBIX construction work.

		FY2015						FY2016						FY2017					
		BES-SUF Operation Funding			Other Funding Source			BES-SUF Operation Funding			Other Funding Source			BES-SUF Operation Funding			Other Funding Source		
Operations Category	Resource	FTEs	Direct ($K)	Burdened ($K)	FTEs	Direct ($K)	Burdened ($K)	FTEs	Direct ($K)	Burdened ($K)	FTEs	Direct ($K)	Burdened ($K)	FTEs	Direct ($K)	Burdened ($K)	FTEs	Direct ($K)	Burdened ($K)
Total Operations	Total	275.0	61,451.1	89,936.5	28.6	7,517.1	9,527.0	289.5	69,858.2	98,011.3	42.7	10,951.0	13,805.7	326.2	84,696.0	120,581.5	52.8	11,903.6	15,907.2
Facility Management and Business Operations	Total	24.5	12,192.2	16,590.2	3.8	959.2	963.7	21.6	11,217.0	15,384.3	4.0	822.1	823.2	20.4	12,152.6	16,378.1	4.3	820.0	826.0
	Manager Effort	2.1	313.5	483.9	2.0	738.8	738.8	2.2	353.5	554.3	1.8	669.3	669.3	2.4	393.0	623.8	1.7	595.2	595.2
	Scientist Effort	0.0	7.7	11.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Engineer Effort	5.0	629.0	970.8	-	-	-	3.9	295.0	462.5	0.2	-	-	4.4	267.9	425.3	0.3	-	-
	Technical Effort	3.2	317.9	490.6	0.1	-	-	3.2	274.3	430.1	0.1	-	-	2.5	174.4	276.8	0.1	-	-
	Post Doc Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Student Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Admin Effort	14.1	537.4	829.4	1.7	130.2	130.2	12.3	232.0	363.8	1.9	101.9	101.9	11.1	11.8	18.7	2.2	112.4	112.4
	M&S		2,700.9	3,788.5		45.3	48.5		2,821.7	3,825.6		9.6	9.8		2,775.6	3,771.0		57.3	61.6
	Travel		75.4	115.8		17.5	18.9		58.8	90.4		11.7	12.5		85.0	131.4		23.2	24.9
Direct	Space Charge		5,337.7	7,625.9		27.3	27.3		5,563.3	8,001.9		29.6	29.6		6,000.0	8,630.0		31.8	31.8
direct elec	Power		2,264.8	2,264.8		-	-		1,618.4	1,655.6		-	-		2,444.9	2,501.1		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Equipment		7.9	8.8		-	-		-	-		-	-		-	-		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R&D Equipment		-	-		-	-		-	-		-	-		-	-		-	-
	R&D Program Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Accelerator Operations	Total	131.4	24,303.5	37,135.8	0.0	-	-	107.5	20,195.5	31,342.9	1.3	271.2	387.3	108.9	25,111.7	37,820.9	2.1	368.3	560.2
	Manager Effort	1.0	258.6	399.1	0.0	-	-	0.9	228.7	358.6	0.0	2.7	4.2	0.4	97.3	154.4	0.0	0.4	0.6
	Scientist Effort	20.3	3,912.3	6,038.1	0.0	-	-	16.4	3,266.8	5,122.2	0.6	114.1	176.8	14.4	2,882.3	4,575.0	1.1	207.6	322.1
	Engineer Effort	46.4	7,599.5	11,728.7	0.0	-	-	40.9	6,975.7	10,937.4	0.6	52.1	80.8	38.9	6,614.3	10,498.6	1.1	96.0	148.9
	Technical Effort	61.5	7,472.1	11,532.1	-	-	-	47.3	5,845.9	9,165.9	0.0	4.6	7.1	53.2	6,458.0	10,250.5	-	-	-
	Post Doc Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Student Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Admin Effort	2.2	180.3	278.3	-	-	-	2.0	185.8	291.4	-	-	-	2.0	183.0	290.5	-	-	-
	M&S		4,569.8	6,756.6		-	-		3,479.6	5,170.3		64.1	81.9		5,689.6	8,253.4		61.6	84.5
	Travel		136.6	209.7		-	-		139.0	213.6		0.9	1.4		107.2	165.7		2.7	4.1
	Space Charge		-	-		-	-		-	-		-	-		-	-		-	-
	Power		(2.0)	(2.0)		-	-		-	-		-	-		-	-		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Equipment		176.2	195.1		-	-		74.0	83.6		32.7	35.2		3,080.1	3,632.9		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R&D Equipment		-	-		-	-		-	-		97.7	118.5		-	-		64.3	88.6
	R&D Program Labor (non-add)	-	-	-	-	-	-	-	-	-	1.2	173.4	268.8	-	-	-	2.1	304.0	471.6
Beamline Operations	Total	101.1	20,937.6	30,310.0	24.6	6,557.9	8,563.2	145.5	35,071.1	46,298.3	37.2	9,857.8	12,595.2	182.2	43,919.3	61,167.4	46.1	10,715.3	14,521.0
	Manager Effort	2.1	519.8	745.5	0.0	-	-	3.2	798.4	1,030.3	0.0	-	-	4.4	1,068.3	1,439.0	0.3	86.2	102.6
	Scientist Effort	31.6	6,029.0	9,041.8	4.5	919.2	1,434.8	41.3	8,229.7	12,135.7	7.5	1,491.4	2,151.4	55.7	10,996.3	16,854.6	9.0	1,904.7	2,992.8
	Engineer Effort	29.4	4,512.8	6,761.4	8.0	1,119.1	1,664.9	46.5	7,287.9	10,403.9	13.6	1,874.1	2,871.1	63.3	9,597.2	14,066.2	18.3	2,701.6	3,850.6
	Technical Effort	27.1	3,317.7	4,966.5	3.7	444.7	559.2	42.2	5,044.3	6,423.3	11.0	1,288.2	1,586.4	46.0	5,752.7	7,806.9	13.9	1,685.6	2,224.6
	Post Doc Effort	2.8	216.2	333.6	7.6	591.0	875.2	3.8	303.3	475.6	5.0	376.4	545.4	3.1	233.8	371.2	4.5	383.0	548.8
	Student Effort	-	-	-	0.3	10.6	16.4	-	-	-	-	-	-	0.5	20.8	33.1	-	-	-
	Admin Effort	8.1	738.4	1,127.6	0.5	35.4	55.8	8.6	891.8	1,265.6	0.1	10.4	16.7	9.3	1,021.2	1,438.5	0.1	13.0	16.9
	M&S		4,726.8	6,242.9		1,745.5	2,097.8		8,666.0	10,475.1		3,601.0	4,068.0		10,580.9	14,037.1		1,945.9	2,440.7
	Travel		307.1	464.1		103.1	158.2		383.6	558.7		81.7	127.9		626.6	940.1		54.1	83.4
	Space Charge		-	-		79.0	114.0		-	-		79.0	113.7		-	-		80.0	116.3
	Power		-	-		2.5	2.5		-	-		2.3	2.3		-	-		4.0	4.1
	Improvements and Upgrades (CE, AIP, GPP etc), Equipment		569.8	626.5		1,507.7	1,584.5		3,466.0	3,530.1		1,053.3	1,112.4		4,021.4	4,180.7		1,857.4	2,140.3
	Improvements and Upgrades (CE, AIP, GPP etc), Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beamline Build Up Equipment		1,713.9	1,877.8		1,822.0	1,910.9		8,375.6	8,843.8		3,595.4	3,852.4		8,433.9	9,045.5		1,394.0	1,611.3
	Beamline Build Up Labor (non-add) (3)	12.1	2,059.5	2,489.4	4.4	594.7	695.7	54.2	8,068.5	9,019.9	14.3	1,915.8	2,224.9	68.8	10,734.2	13,508.4	18.8	2,727.6	3,292.4
	R&D Equipment		468.1	668.9		635.9	800.6		744.6	1,026.6		453.7	573.8		793.7	1,140.4		119.5	171.0
	R&D Program Labor (non-add)	12.9	2,233.8	3,447.6	8.7	703.0	1,048.4	15.0	2,526.1	3,960.7	6.4	567.7	841.9	13.8	2,241.3	3,557.6	4.5	383.0	548.8
ES&H/QA	Total	18.0	4,017.8	5,900.5	0.1	-	-	14.9	3,374.6	4,985.8	0.2	-	-	14.7	3,512.5	5,215.0	0.2	-	-
	Manager Effort	1.0	258.5	399.0	-	-	-	1.0	274.1	429.8	-	-	-	0.9	258.2	409.8	-	-	-
	Scientist Effort	2.6	514.3	793.7	-	-	-	1.0	235.8	369.7	-	-	-	1.3	262.1	416.0	-	-	-
	Engineer Effort	11.2	1,513.3	2,335.6	0.1	-	-	10.5	1,452.5	2,277.4	0.2	-	-	10.2	1,439.9	2,285.5	0.2	-	-
	Technical Effort	0.2	29.0	44.8	-	-	-	0.1	9.2	14.5	-	-	-	0.1	6.9	10.9	-	-	-
	Post Doc Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Student Effort	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Admin Effort	3.0	258.8	399.4	-	-	-	2.3	152.5	286.1	0.0	-	-	2.2	132.8	210.7	0.1	-	-
	M&S		1,440.3	1,922.5		-	-		1,233.2	1,585.1		-	-		1,387.6	1,843.4		-	-
	Travel		3.6	5.6		-	-		9.2	14.2		-	-		25.0	38.7		-	-
	Space Charge		-	-		-	-		-	-		-	-		-	-		-	-
	Power		-	-		-	-		-	-		-	-		-	-		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Equipment		-	-		-	-		8.0	9.0		-	-		-	-		-	-
	Improvements and Upgrades (CE, AIP, GPP etc), Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R&D Equipment		-	-		-	-		-	-		-	-		-	-		-	-
	R&D Program Labor (non-add)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. FY 17 data is based on plans as of March 2017
2. Other Funding source data is made up of the following: LDRD, Proprietary, SPP (LSBR, Accustrata, Wavefront Preserving Mirrors, Saw-tooth Kinoform Lenses), SPP Partner Beamlines, HEX
3. BES-SUF Funding source data is made up of the following: NSLS II OPS, Other BES OPS, Beamline Development, BDN, BNL Partner
4. Data which is excluded is made up of the following: NEXT, ABBIX, NSLS II Project, NSLS I OPS
5. Electric power is both direct and indirect. Indirect is distributed via a rate of .85% FY15 ($321.4K), 1.2% for FY16 ($430.0K) and estimated at 1.2% for FY17 ($524.0K).

Table 1.iii.9: FY2015-FY2016 Operation Budget Details and FY2017 Operation Budget Projections

1.iv Organization

Provide a detailed organizational chart which includes the names of all facility employees. Describe the functions of each major organizational unit and of the groups within these units. In addition, provide a summary table that indicates the job category (manager, admin, scientist, engineer, technician, post doc, and student), the organization unit, and the fraction of source(s) of support (BES Operation fund for regular function, BES Operation fund for beamline development, NEXT project, overhead, LDRD, and other), for each staff during FY2016.

a. NSLS-II Organization Chart as of November 1, 2016

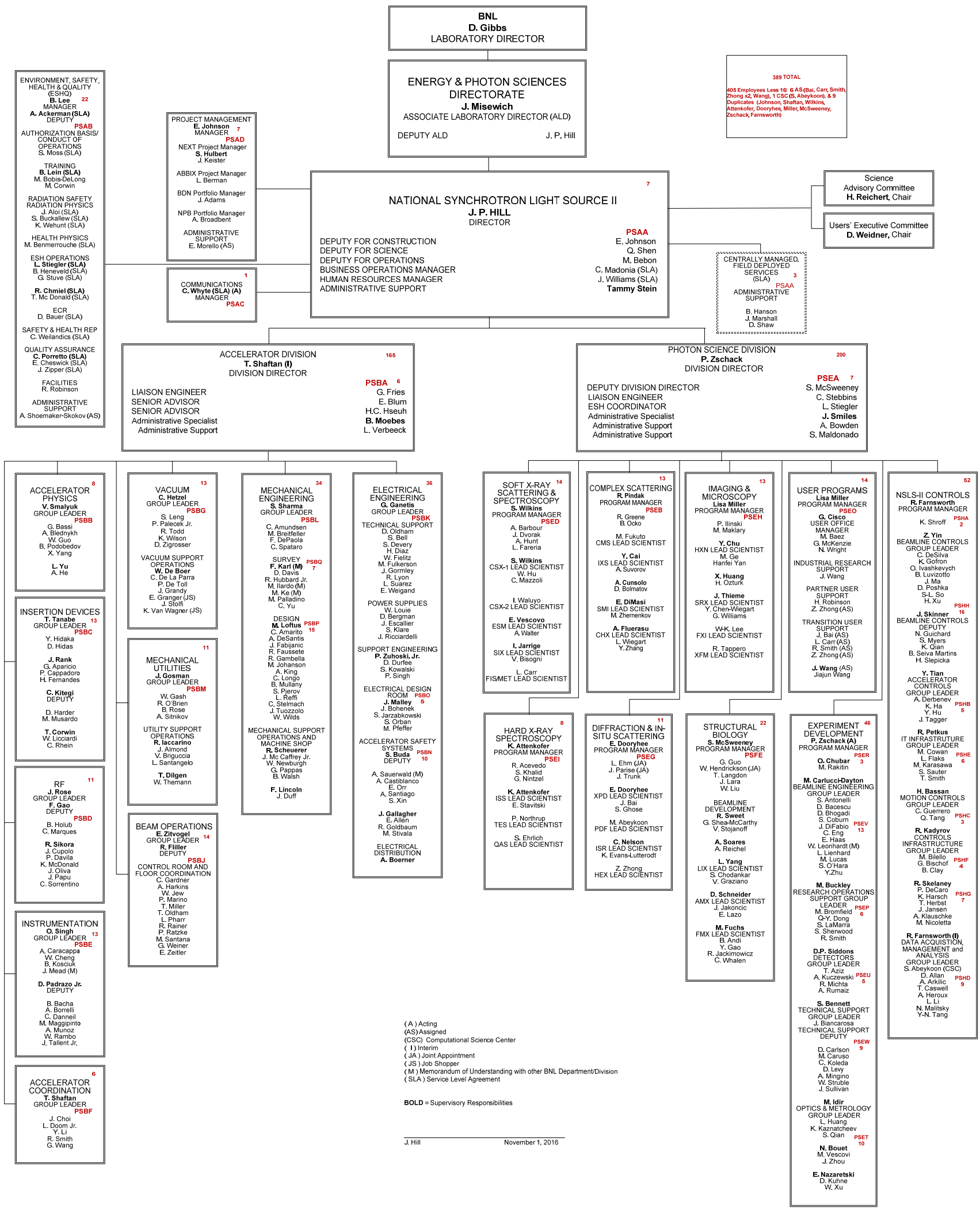

Figure 1.iv.a.1: NSLS-II Org Chart, November 1, 2016

b. List of employees who left BNL after November 1, 2016.

Employees who left BNL after 11/1/2016:

Name	Work Group		
BARONE S.	PSBM	-	MECHANICAL UTILITIES
CHABOT D.	PSHD	-	DATA ACQUISTION, MANAGEMENT & ANALYSIS
DACOS G.	PSBL	-	MECHANICAL ENGINEERING
DALSACE R.	PSBJ	-	BEAM OPERATIONS
DEOLIVEIRAOM D.	PSHH	-	BEAMLINE CONTROLS
DILL E.	PSHD	-	DATA ACQUISTION, MANAGEMENT & ANALYSIS
GHOSH V.	PSAB	-	ENVIRONMENT, SAFETY, HEALTH & QUALITY
ILTIS G.	PSHD	-	DATA ACQUISTION, MANAGEMENT & ANALYSIS
KALBFLEISCH S.	PSEH	-	IMAGING & MICROSCOPY
KISS R.	PSAB	-	ENVIRONMENT, SAFETY, HEALTH & QUALITY
KISS S.	PSAD	-	PROJECT MANAGEMENT
KULPIN J.	PSBD	-	RF
LAUER K.	PSHD	-	DATA ACQUISTION, MANAGEMENT & ANALYSIS
LEWIS W.	PSHH	-	BEAMLINE CONTROLS
LOFFREDO R.	PSBL	-	MECHANICAL ENGINEERING
LOWERY A.	PSEH	-	IMAGING & MICROSCOPY
MAGILL J.	PSBL	-	MECHANICAL ENGINEERING
MENDEZ T.	PSAB	-	ENVIRONMENT, SAFETY, HEALTH & QUALITY
MESSANA C.	PSEO	-	USER PROGRAMS
MILLER L.	PSAA	-	NATIONAL SYNCHROTRON LIGHT SOURCE II
PEDERSEN K.	PSBK	-	ELECTRICAL ENGINEERING
PRICE A.	PSEV	-	BEAMLINE ENGINEERING
QUETZ A.	PSEF	-	COHERENT HARD X-RAY SCATTERING
REICHEL A.	PSEE	-	INTELASTIC X-RAY SCATTERING
RIVERA P.	PSBM	-	MECHANICAL UTILITIES
SCHWARZ M.	PSBM	-	MECHANICAL UTILITIES
SHI YINGBO	PSED	-	SOFT X-RAY SCATTERING & SPECTROSCOPY
SUMMERS T.	PSBJ	-	BEAM OPERATIONS
TUTUNCU G.	PSEG	-	DIFFRACTION & IN-SITU SCATTERING
USACK V.	PSBG	-	VACUUM
YANG, L.	PSBB	-	ACCELERATOR PHYSICS

c. List of current employees who moved working groups within FY16.

Current Employees Who Moved Working Group within FY16:

Name	Previous Work Group			Current Work Group		
APARICIO G.	PSBL	-	MECH'L ENG.	PSBC	-	INSERTION DEVICES
BIANCAROSA J.	PSEH	-	IMAGING & MICROSCOPY	PSEW	-	TECHNICAL SUPPORT
BLUM E.	PSHA	-	NSLS-II CONTROLS	PSBA	-	ACCELERATOR DIVISION
DELLA PENNA JR. A.	PSBC	-	INSERTION DEVICES	-------	-	INSTRUMENTATION DIV
DUFF JR. J.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
FLILLER R.	PSBF	-	ACCEL. COORDINATOR	PSBJ	-	BEAM OPERATIONS
GALIOTO P.	PSBG	-	VACUUM	-------	-	COLLIDER ACCEL. DEPT.
KHALID S.	PSEP	-	RESEARCH OPER. SUP. GRP.	PSEI	-	HARD X-RAY SPECTROSCOPY
LEIGHLEY T.	PSAB	-	ESH&Q	-------	-	BIOLOGY
LINCOLN F.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
MAKLARY M.	PSER	-	EXPERIMENT DEV.	PSEH	-	IMAGING & MICROSCOPY
MC CAFFREY JR. J.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
MC GEE L.	PSAA	-	NSLS-II	-------	-	PHYSICS DEPT.
MORELLO E.	PSEA	-	PHOTON SCIENCE DIV.	PSAD	-	PROJECT MGMT.
NEWBURGH W.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
OCKO B.	PSEA	-	PHOTON SCIENCE DIV.	PSEB	-	COMPLEX SCATTERING
PAPPAS G.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
PULEO D.	PSBL	-	MECH'L ENG.	-------	-	COLLIDER ACCEL. DEPT.
RISI N.	PSBM	-	MECH'L UTILITIES	-------	-	ENERGY & UTILITIES
SCHEUERER R.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
SELETSKIY S.	PSBB	-	ACCEL. PHYSICS	-------	-	COLLIDER ACCEL. DEPT.
SMITH R.	PSBJ	-	BEAM OPERATIONS	PSBF	-	ACCEL. COORDINATOR
WALSH B.	PSBL	-	MECH'L ENG.	PSBP	-	DESIGN
WILLEKE F.	PSBA	-	ACCELERATOR DIV.	-------	-	COLLIDER ACCEL. DEPT.

d. NSLS-II Facility: Functions by Organizational Group

Provided below is a description of each major organization unit and the groups within these units.

Management Group:

Director's Office - PSAA

Consisting of the NSLS-II Director, Deputies, senior managers and administrative staff, this group provides strategic level direction of the NSLS-II science program, beamline construction and facility operations. Functions include strategic planning, developing budgets to support plans, establishing priorities, managing NSLS-II financial and human resources, interacting and communicating with DOE - local and HQ, other light sources and user facilities, the user community, the broader scientific community, the public, employees, and other key stakeholders. The work includes development of a strong, vibrant, user community through oversight of the beam time allocation process and management of the beamline development process, including partner user access. A key function is to ensure excellence in operation of the facility by establishing a strong operating culture and deploying performance management and conduct of operations programs. The Business Operations Manager and Human Resources Manager within this group are purchased under a Service Level Agreement with their respective directorates.

Communications- PSAC

This group assists NSLS-II senior management and staff at all levels with developing strategies, messaging, and print and electronic media products, to enable management to continuously provide relevant information to all interested and affected stakeholders. Functions also include conducting tours and responding to media inquiries.

Project Management- PSAD

This group assists NSLS-II senior management and staff with the development of, execution/ management of and close out of NSLS II defined Projects. Functions are dependent on size and/or complexity of the project. These functions may include WBS development, cost estimating, scheduling, baseline development, baseline management, baseline change control and external and internal project reporting for the project performance measurement baseline (cost, schedule and scope baseline). This group will also interact early with potential sponsors in the development of new projects.

Business Operations-PSCI

The Business Operations staff, reporting to the Business Operations Manager (Director's Office), provides financial management services (planning, budgeting, analysis, tracking, and reporting), procurement and contracting support, property management (inventorying and tracking accountable property, transferring and excessing equipment) and stores and inventory management (managing shipping and receiving and stockroom operations). This

group also reviews and processes invoices, monitoring time and effort reporting and budgeting and manages the credit card program. Like the Business Operations Manager, this group is provided under a Service Level Agreement (SLA) with the Laboratory's Business Operations Directorate

Human Resources-PSCC

The Human Resources (HR) staff reporting to the Human Resources Manager (Director's Office) provides support to senior management in the planning of the human resources needed to support the organization's strategic program plan and implements Laboratory HR policies, procedures and programs and services pertaining to the human resources of NSLS-II including diversity and inclusion, change management, organizational development, performance management, talent management, problem resolution, succession planning and workforce planning. The HR staff also performs recruiting and on-boarding and, advises management and coordinates the termination, transfer, and reduction in force processes. Like the Human Resources Manager, this group is provided under a Service Level Agreement (SLA) with the Laboratory's HR Directorate.

Field Deployed Services

This group provides administrative assistance to Department Management managers and the Business Operations, Human Resources, Project Controls and Quality Assurance Groups.

Environment, Safety, Health & Quality (ESHQ)

The ESH&Q Manager is a direct report to the NSLS-II Director. The Manager provides management oversight for the following functions: Authorization Basis Management, Conduct of Operations, Training, Radiation Safety, ESH Operations/Integrated Safety Management, and Quality Assurance. Staff performing these functions are principally provided through the Field Deployed Services Model through Service Level Agreements with the central organization.

Authorization Basis/Conduct of Operations-PSAB

The Authorization Basis Manager ensures NSLS-II operations are appropriately documented in authorization basis documents/safety bases and for managing the authorization basis documents. Significant effort is applied to NSLS-II operations through implementation of the Unreviewed Safety Issue process to ensure all facility modifications and operations continue to conform to the authorization basis boundaries. The AB Manager also manages the NSLS-II Conduct of Operations program. In this capacity the ABM ensures the approved conduct of operations matrix is maintained in accordance with DOE and BNL requirements. The ABM also serves on the BNL Conduct of Operations Review Board.

Training-PSAB

The training group staff provides all services needed to ensure staff, contractors, and users are trained and qualified to operate and continue to build-out NSLS-II. These functions include analyzing work assignments to identify and document required training, interacting with the Laboratory training staff and central systems, planning, developing, and

coordinating (or directly delivering) training courses, monitoring training status and providing status reports to managers and supervisors to ensure only qualified personnel are used to perform key functions.

Radiation Safety/Health Physics-PSAB

The Radiation Safety/Health Physics group develops and implements operational health physics (radiation surveys, personnel monitoring, radiation monitoring) and prepares Monte Carlo simulations in the design/specification of shielding and beamline/accelerator design. The group prepares and implements radiation survey plans, and compares survey results to simulated analyses to ensure shielding as designed meets shielding design criteria. The group manages and specifies radiation monitoring systems and ensures these systems remain calibrated and fully integrated into the NSLS-II personal protection systems.

ESH Operations-PSAB

ES&H staff provide ES&H support to NSLS-II construction projects and operations, through implementation of an approved Integrated Safety Management (ISM) program, to assure safe, secure, and compliant operation of the facility and that all operations are performed in an environmentally sound manner Subject matter experts support work planning and control, experimental safety review, and accelerator safety processes through identifying ES&H hazards and the controls needed to mitigate or eliminate them, monitoring work performed for conformance with controls, inspecting equipment and work spaces and utilizing worker feedback to continuously improve operations. The staff ensures compliance with the Accelerator Safety Envelope (ASE) and related authorization basis documents through reviewing engineering designs, installation work in the field, and operating procedures, monitoring of operations, executing a rigorous Safety System Work permit program and preparing and implementing Personnel Protection System certification test procedures. ES&H also manages the readiness assurance processes (IRR/ARR/ESR) for the accelerators, beamlines, laboratories, and for ensuring beamline readiness for user operations.

Quality Assurance-PQQA

The group provides quality control and quality management expertise and services for the operations and maintenance of the accelerator and beamlines as well as for the review of engineering designs, procurement/fabrication documents, installation, construction, and testing/acceptance of new hardware and software to ensure conformance with established criteria and specifications. The staff manages the organizational assessment and events and issues management programs, and analyzes and reports performance data to identify trends that may need management attention. The group also manages the action tracking systems used by NSLS-II to ensure completion of actions identified during reviews and assessments and for tracking certification and calibration dates for PPS systems and other equipment requiring routine calibration (e.g., radiation monitors, gauges etc.). The group develops and continuously updates the NSLS-II Department “Dashboard” that includes a summary and analysis of all performance parameters tracked by senior management.

Facilities-PSAE

Facilities staff coordinates all of the operations and maintenance, repair, service calls, and minor construction activities for the NSLS-II conventional facilities that are performed by the Laboratory's Facilities and Operations directorate, provides space management and workspace support services (furniture, phones, data) to all building occupants, and supports the logistics for reviews and other events. This group also manages the security and emergency management programs, including planning, preparation and response to severe weather events, operating the security access control system, and managing the vehicle management program.

Accelerator Division Groups

Accelerator Division Management-PSBA

Accelerator Division (AD) management provides oversight of accelerator operations maintenance and development, manages division finances including budget planning, manages the support of beam line construction projects, defines and organizes the Accelerator R&D program, manages AD staff, interfaces to the Photon Science Division and facility management, and provides stewardship for safe and compliant performance of the division work.

Accelerator Physics-PSBB

The Accelerator Physics group develops, prepares, performs and evaluates accelerator studies in order to improve and develop accelerator performance, provide support to beam operators to analyze problems and issues, commission new insertion devices and frontends, design and build improved accelerator operations software to automate intricate optimization procedures to maintain full accelerator performance, assume ownership of the synchrotron radiation protection system including orbit interlock ("active interlock)" and fast orbit feedback, improve accelerator design and develop upgrade plans, perform accelerator R&D, contribute to the specification of new insertion devices, publish results of NSLS-II performance increase, and improve accelerator physics tools (theory and software, procedures).

Insertion Devices Group-PSBC

The Insertion Device group operates, maintains, troubleshoots and develops insertion devices which are in operation. The group also designs, procures, measures and shims new insertion devices. For this purpose the group maintains and develops a state of the art magnetic measurement laboratory. The group also performs R&D on novel insertion devices and insertion device subsystems.

RF Group-PSBD

The RF group operates, maintains and develops RF systems which are in operation. The group further performs RF development and constructs new RF systems in-house. The group's mission also includes RF R&D. The RF systems already in operation include: LINAC RF power sources, electron source system, accelerating unit, Booster RF power source, booster RF

cavity, storage ring superconducting RF cavities including cryogenic valve box and Storage Ring RF power system. The group is further responsible for low-level RF controls. The group maintains the RF blockhouse for RF testing, and klystron test stands. The group will also construct spare superconducting cavities in-house.

Instrumentation Group-PSBE

The group provides maintenance, troubleshooting repair and development of all beam diagnostic systems, and performs instrumentation R&D. The group is responsible for the following systems: BPM system, loss monitor system, beam current monitoring, bunch length measurement, optical imaging of the beam, X-ray imaging of the beam, broadband transverse damper system, tune measurement system, Xbpm, safety rated current monitor system, scraper system, fluorescence monitors, OTR monitors, and beam screen system in beam line frontends. The instrumentation group also assists in layout of the new insertion device straight sections, and in the developing of controls software to visualize the output of diagnostic systems.

Accelerator Coordination Group-PSBF

The group coordinates and prioritizes the NSLS-II accelerator development, coordinates and prioritizes maintenance activities with the subsystem owners, executes configuration control of radiation shielding and other safety measures, coordinates accelerator modes of operation and operation schedule with beam line staff and ESH, and coordinates significant interventions. The group also works on commissioning new front ends and insertion devices. The group also develops study budget and schedules, reacts on operating emergencies, troubleshoots and optimizes injector and storage ring, reports on significant events that take place in operations and shutdowns, analyzes trends in operations, communicates across AD and NSLS-II with their findings and requests for studies, tools, observations of performance.

Vacuum Group-PSBG

The vacuum group maintains and develops all accelerator vacuum systems for LINAC, transfer lines, booster synchrotron, and Storage ring including the beam line frontends. The systems include vacuum chambers, shielded bellows, gate-valves, ion pumps, TSPs, and synchrotron radiation absorbers including water cooling circuits with their flow control system. The vacuum group is also the owner of the vacuum equipment protection system based on a PLC system. The group maintains a vacuum laboratory with a cleaning facility and a 900 °C brazing oven. The vacuum group assists the insertion device group in vacuum aspects of the insertion devices. The vacuum group also provides vacuum support for beam line operation. The group maintains a system of mobile pump-carts with leak check equipment, turbo pumps, and residual gas analyzers as well as complete bake-out systems. The vacuum group also assists in the vacuum design and construction of new beam lines and in the procurement of vacuum components.

Mechanical Utilities-PSBM

The mechanical utility group is responsible for design, construction, development, operation and maintenance of water cooling systems including central cooling tower systems and 13 satellite DI water cooling systems and the chilled water distribution system ("process chilled water"). The group also assumes responsibility for the liquid He plant, which includes a liquid N_2 system as well as the liquid N_2 system for beam line operations. The group is also responsible for the compressed air system. The group also provides venting system and engineering support for the operation of the HVAC systems for the accelerator tunnels and experimental floor.

A large fraction of the efforts of this group is devoted to accelerator operations. In addition, the group's support is required for beam line operation. New beam line projects need extension of existing mechanical utilities which are planned and executed by this group.

Beam Operations Group-PSBJ

The main task of the group is to perform efficient and compliant beam operations of the NSLS-II accelerator complex. They perform beam operations in the control room, maintain control room procedures, and organize control room safety functions. During shut down and maintenance days, they monitor water and cryogenic systems and processes, such as vacuum bake out, and support technical installation and PPS recertification efforts. They maintain the full functionality of the control room and assume responsibility for local safety coordination for any emergency situation in the facility. They generate operation schedules and operating statistics in collaboration with the coordination group. The subgroup of floor coordinators secures the accelerator tunnel and assists in the process of getting the beam lines ready for beam operations. The group also provides general technical support and safety oversight for beam line users, in particular during off- hours.

Detailed List of Responsibilities

- Responsible for safe and efficient operation of the entire accelerator complex through the lead operator. All NSLS-II operators are trained to the level of lead operator.
- Lead Operator will call in technical, professional and scientific staff in response to issues that affect the quality of the accelerator beam or that limit user beam time.
- Ensures that the accelerator is configured for safe operation of all enabled beamlines.
- Floor Coordinators ensure that beamlines have all required safety component checklists in place.
- Floor Coordinators assure that a valid Safety Approval Form is in place for all beamlines that will be enabled.
- Floor Coordinators enable beamlines.
- Floor Coordinators and Operators will help to check in and issue TLDs to users arriving during off hours.
- Qualified Floor Coordinators and Operators may perform Electrical Equipment Inspections of user equipment during off hours.
- Operators and Floor Coordinators act as Local Emergency Coordinator during drills and unplanned emergency events.

- Operators and Floor Coordinators are point contacts for all issues that arise in the NSLS-II complex.
- Operators and Floor Coordinators are on duty 24/7 during beam operations.

Mechanical Engineering Group

This group is responsible for a wide range of accelerator subsystems and also has a number of specialized subgroups**.**

Mechanical Engineering-PSBL

This team (which does not form a subgroup and staff report the MEG leader) performs general mechanical engineering support for the operation of all accelerator mechanical subsystems. This includes magnet and girder systems, general support structures, and beam line frontends. The team also performs design, and construction of new beam line frontends as part of new beam line projects. The group performs thermal, structural and vibration analyses.

The majority of the labor effort of this team is for construction of new beam line frontends for new beam lines.

Survey Subgroup-PSBQ

This group performs all equipment survey for the entire facility (accelerator subsystems as well as beam line components) and also assists in the installation of accelerator and beam line components. The team performs high precision alignment of magnets and vacuum components in the accelerator tunnel. These labor resources are shared with the Collider Accelerator Department (CAD) at BNL.

Mechanical Design-PSBP

The mechanical designers produce all mechanical drawings for design, construction and installation of components for both accelerator systems and beam lines.

Mechanical Support Operations and Machine Shop

This subgroup of mechanical technicians performs all mechanical assembly, testing, installation and maintenance for magnets and supports, beam line frontends, and supplemental shielding systems. Most of the group's activities are on accelerator systems. The group also operates and maintains the NSLS-II machine shop in building 726.

Electrical Engineering Group-PSBK

The EEG is a diverse group which combines several subgroups of the electrical engineering group.

Technical Support Subgroup

This is a team of technicians that provides electric support services throughout the facility and also support the engineers within the power supply subgroup. This includes support of magnets, power supplies, UPSs, cabling, cable trays and equipment enclosures. They perform the necessary maintenance, repair, rework, and LOTO of these subsystems. They do the purchasing and management of spare parts. They are also the technicians that support the electrical technician needs of the insertion device and front end groups. In addition, they perform electrical and PPS installation work for the construction of new beamlines.

Power Supplies Subgroup

The group is responsible for maintenance, trouble shooting and repair of the more than 1000 power supplies (PS) of the NSLS-II accelerator complex for linac, booster, transfer-lines and storage ring. Each supply typically consists of a number of subsystems, circuit breaker, DC voltage supply, power converter, regulator, DC powered amplifier, power supply interface, power supply controller. Several PS share a PLC for power supply interlock. Power supply interlocks also include the magnet protection system. The Power Supplies Subgroup is responsible for: operation, maintenance, optimization and upgrades of all ~900 DC and ramped power supplies, their controls, calibration and calibration tools for monitoring of their output, PS interfaces to the power enclosures, utilities, interfaces to the accelerator EPS and PPS systems, safety and documentation, support ops 24/7 with a call in list. Members of this subgroup work together with the Diagnostics and Instrumentation Group on common projects like FOFB and with Controls group on PSI/PSC interfaces and feedbacks.

Support Engineering Subgroup

This group is responsible for operation, maintenance and development of the pulsed beam transfer equipment which are Booster injection and extraction kicker and septa and storage ring injection kicker and septum magnets including pulsers, trigger electronics. The members of this group provide technicians support of all EE activities including power distribution, power supply enclosures, cabling and power interfaces to the loads, switchgear, interfaces to utilities (cooling water), help with magnetic measurements of the accelerator magnets, planning, coordination and documentation of the electrical work within the area of the group responsibility, electrical safety protocols. This subgroup supplies support to all other AD groups, for instance, to the ID group for helping with ID PS and controls.

Electrical Design Room-PSBO

This group produces all electrical design drawings, one line diagrams and cable pulling plans for both accelerator and beam line system. The electrical design room is responsible for: all design and documentation work related to developments, repairs and maintenance of the power systems including DC, ramped and pulsed power supplies, electrical infrastructure, power enclosures, PPS, EPS, cable pulling, etc. This subgroup keeps all documentation and drawings that come from vendors, and maintain lists of electrical spares.

Accelerator Safety Systems Subgroup (PPS Electrical Engineering)-PSBN

This group is responsible for design, construction, and maintenance of the personal protection system (PPS). Most of the system is part of the accelerator, but it also includes PPS for the beam line hutch-systems. The Accelerator Safety Systems subgroup is responsible for developing and maintaining the EPS and PPS systems, including those for the accelerator enclosures, beamlines, interlocks with reachbacks to different subsystems (i.e., PS, RF, ID, FE, Vacuum, Diagnostics and Instrumentation, etc.). The subgroup is responsible for equipping the MCR with HMI panels, developing relevant PPS and EPS documentation and supporting machine operations 24/7.

Electrical Distribution Subgroup (Assigned Electricians) - PSBS

This group is headed by an engineer and is otherwise staffed by assigned electricians from the central laboratory organization. This group is responsible for all AC distribution and the UPS-system. They also perform installations and maintenance of conduit for PPS cables. The work of this group includes systems for accelerator and beam line installation as well as general building electrical installations. The Electrical distribution subgroup performs planning and executing of all electrical distribution activities (cable pulling, inventory lists, interfaces to cable trays) for the machine and beamlines with support from assigned electricians and F&O reps.

Photon Science Division Groups

Photon Science Division Management-PSEA

Photon Science Division management provides oversight of beamline commissioning and operations and R&D activities, manages division finances including budget planning, manages the support of beamline construction projects, defines and organizes the Photon Science Division programs, manages Photon Science Division staff, interfaces to the Accelerator Division, facility management and the User Community, and provides stewardship for safe and compliant performance of the division work.

Soft X-ray Scattering & Spectroscopy Program-PSED

Includes coalition of beamlines with common technical and scientific themes that includes inelastic scattering, coherent scattering, spectroscopy and imaging. Responsibilities range from oversight of beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in hard condensed matter and other widely diverse scientific disciplines. Program operates these beamlines and develops new user communities. Program also develops instrumentation & techniques, and performs individual and collaborative research in areas that extend inelastic scattering, coherent scattering, spectroscopy and imaging capabilities at NSLS-II in the 200 eV-2000 eV spectral range. Within the Soft x-ray scattering and spectroscopy program, there are 6 beamlines;

1) CSX-1: Coherent soft x-ray scattering, focused on soft x-ray resonant scattering studies of hard condensed matter systems.

2) CSX-2: Soft x-ray spectroscopy and polarization, focused on ambient pressure photoemission of chemical processes and soft x-ray absorption spectroscopy.
3) ESM: Photo emission microscopy, including ARPES and LEEM/PEEM, focused on studies of hard condensed matter and catalysis.
4) SIX; Soft x-ray inelastic scattering, focused on low energy excitations in condensed matter systems.
5) FIS/MET; two beamlines for IR studies of solid state systems under high pressure and extreme conditions.

Hard X-ray Spectroscopy Program-PSEI

Includes coalition of beamlines with common technical and scientific themes that includes hard and tender x-ray spectroscopy. Responsibilities range from oversight of beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in widely diverse scientific disciplines. Program operates these beamlines and develops new user communities. Program also develops instrumentation & techniques, and performs individual and collaborative research in areas that extend spectroscopy capabilities at NSLS-II. The program also coordinates work associated with the development and operations of beamlines developed in partnership with NIST. Within the hard x-ray spectroscopy program, there are 6 beamlines:

1) ISS: Inner shell spectroscopy of a range of systems including catalytic reactions in operando
2) QAS; Quick absorption and scattering studies of a wide range of problems including chemical and physical science
3) TES: Tender x-ray absorption spectroscopy covering a wide range of problems including geoscience and environmental science
4) SST-1 and SST-2: Spectroscopy Soft and Tender. These are two beamlines with a unique concept in which two different insertion devices can feed the same endstation, or two separate branches, providing an energy range from 100 eV to 7.5 keV for XPS/NEXAFS and XPS. Beamlines will be operated in partnership with NIST.
5) BMM: Material measurement. This is an x-ray scattering and absorption spectroscopy beamline operating in the range of 4.5 to 40 keV. The beamline will be operated in partnership with NIST.

Complex Scattering Program-PSEB

Includes coalition of beamlines with a common technical theme that includes inelastic scattering, coherent scattering, and small- and wide-angle scattering (SAXS/WAXS). The SAXS/WAXS technique covers time-resolved, resonant scattering, grazing incidence, and liquid surface scattering. Responsibilities range from oversight of beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in soft matter and other widely diverse scientific disciplines. Program operates these beamlines and develops new user communities. Program

also develops instrumentation & techniques, and performs individual and collaborative research in areas that extend inelastic scattering, coherent scattering, and SAXS/WAXS capabilities at NSLS-II. Within the Complex Scattering program, there are 4 beamlines:

1) IXS: inelastic x-ray scattering studying low energy excitations with an emphasis in soft matter and high pressure systems
2) CHX: hard x-ray coherent scattering studies of fluctuations and dynamics in complex hard and soft matter systems
3) CMS: intelligent exploration of parameter space in SAXS/WAXS from complex materials systems
4) SMI: SAXS/WAXS studies of the structure and dynamics of soft matter interfaces

Diffraction & In-situ Scattering Program-PSEG

Includes coalition of beamlines with common technical and scientific theme that includes hard x-ray scattering and diffraction. Responsibilities range from oversight of beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in widely diverse scientific disciplines. Program operates these beamlines and develops new user communities. Program also develops instrumentation & techniques, and performs individual and collaborative research in areas that extend x-ray scattering and diffraction capabilities at NSLS-II. Within the Diffraction and In Situ Scattering program, there are 4 beamlines:

1) XPD: X-ray powder diffraction branch line offers the ability to collect structural data at high energies (30 - 70 keV), offering exceptional diffraction capabilities such as high throughput, in situ and time-dependent measurements and high angular resolution on the same instrument.
2) PDF: X-ray atomic pair distribution function branch line enables studies of nanoscale fluctuations and hidden broken symmetry phases in next generation complex materials
3) ISR: Integrated in-situ and resonant hard x-ray studies taking advantage of a variety of x-ray scattering techniques (e.g., resonant x-ray scattering, crystal truncation rod measurements, x-ray reflectivity, grazing incidence small-angle x-ray scattering, and grazing incidence diffraction) focused on hard condensed matter systems and problems of thin film growth.
4) HEX: This high energy x-ray scattering beamline will be focused on operando studies of a variety of systems including especially energy storage systems and engineering materials. It is being developed in partnership with New York State.

Imaging & Microscopy Program-PSEH

Includes coalition of beamlines with common technical and scientific theme that includes scanning probe microscopy and full-field imaging. Responsibilities range from oversight of beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in widely diverse scientific disciplines. Program operates these beamlines and develops new user communities. Program also develops instrumentation & techniques, and performs individual and collaborative research in areas that

extend the imaging and microscopy capabilities at NSLS-II. Within the Imaging & Microscopy program, there are 4 beamlines:

1) HXN: Hard x-ray nanoprobe studies of structural and X-ray fluorescence and diffractive imaging with world-leading spatial resolution
2) SRX: Submicron resolution x-ray spectroscopy will enable simultaneous x-ray fluorescence and transmission measurements with sub-µm to sub-100 nm spatial resolution with an incident x-ray beam energy of 4.65-25 keV
3) XFM: X-ray fluorescence microprobe optimized for spatially-resolved characterization of elemental distribution and chemical speciation in "as-is" samples that are heterogeneous at the micrometer scale
4) FXI: Full field x-ray imaging will house a Transmission X-ray Microscope (TXM) with 30 nm spatial resolution and 20-40 micron field of view

Structural Biology Program-PSFE

Includes coalition of beamlines with common technical and scientific theme that includes macromolecular crystallography and solution scattering. Responsibilities range from beamline design, development, and construction to beamline commissioning and operations and support for high impact user science programs in life sciences. Program operates these beamlines and develops new user communities. Program also develops instrumentation & techniques, and performs individual and collaborative research in areas that extend MX and solution scattering capabilities at NSLS-II. This program also coordinates the development and operations of beamlines developed in partnership with Case Western Reserve University (CWRU), and New York Structural Biology (NYSBC). Within the Structural Biology program, there are 5 beamlines:

1) FMX: frontier microfocusing macromolecular crystallography supports single- and multi-axis MX projects, micro-focus crystallography, serial crystallography, and data collection at cryo- and room temperature. To be operated by NIH/BER.
2) AMX: Highly automated macromolecular crystallography is a high-flux mini beam of 4 µm size and low divergence and readily available larger beams to 100 µm . To be operated by NIH/BER.
3) LIX: Life science x-ray scattering . This is a small angle scattering beamline specifically for life science applications. To be operated by NIH/BER.
4) XFP: X-ray footprinting for in vitro and in vivo structural studies of biological macromolecules is a 3-pole wiggler beamline at 17-BM providing world-leading X-ray Footprinting capabilities for solution state studies of biological macromolecular structure and dynamics. The beamline will be operated in partnership with Case Western Reserve University.
5) NYX: NYSBC Microdiffraction: this beamline will perform state of the art protein crystallography with particular attention to anomalous diffraction methods. The beamline will be operated in partnership with NYSBC.

Experiment Development Program-PSEW

Includes several groups that support operations, beamline development, and R&D activities. Also, staffing to provide calculations of NSLS-II sources and beamline optics to support beamline optics design, beamline commissioning, and beamline operations performance evaluations.

Beamline Engineering Group-PSEV

Mechanical engineering group supporting beamline development, beamline operations, and other Photon Science Division mechanical engineering efforts. Work involves development of specifications for beamline component procurements, overall beamline designs to meet technical objectives, endstation design and assembly, and engineering support for all other groups.

Research Operations Support Group-PSEP

Group supports operations and provides oversight of LOB laboratory facilities, including management of the NSLS-II equipment pool. Group coordinates operations and development activities, assures procurement documentation is compliant with beamline technical needs, and plans and executes required design reviews of experimental systems. Group also coordinates maintenance and certification of common beamline systems such as cryogenic systems & cryocoolers, ODH monitoring, and hutch system maintenance.

Detectors Group-PSEU

Group develops advanced detector systems which address specific opportunities for NSLS-II beamlines, provides advice and assistance to beamline scientists on detector issues, and explores new technologies and concepts in detector systems with a view to their potential applications at NSLS-II.

Technical Support Group-PSEW

Technical staff pool supporting beamline developments, beamline equipment installations, and beamline operations.

Optics and Metrology Group-PSET

Group develops, tests, and operates tools to measure and optimize the relevant properties of optical elements used in NSLS-II beamlines. Group fabricates and tests x-ray focusing and dispersive optical elements for use in NSLS-II beamlines. Efforts in the group also include microscopy development, nano- positioning, nano-sensing and mechanical metrology.

User Programs-PSEO

Includes several user support functions:

User Office

Primary point of contact with user community. Group manages the beamtime proposal system, Facilitates User and Guest access to the NSLS-II to perform experiments, assists and supports the NSLS-II user community with beam time applications, user agreements, logistical arrangements, and other needs of NSLS-II users. Group coordinates the annual Users' Meeting and workshops, and collects and maintains records and required statistical information related to the NSLS-II user programs, and performance metrics of the facility.

Industrial Research Support

Effort to develop and promote NSLS-II Industrial Research. Includes engagement of scientific and industrial community, outreach to attract new industrial users, collaborative research, and technical services for industrial users.

Partner User Support

NSLS-II support for partner user beamline operations. Includes maintenance and routine servicing of beamlines developed and operated with externally funded partners.

Transition User Support

Support for former NSLS users at other light source facilities. Effort includes support at ALS, and APS for spectroscopy users, infrared users, energy dispersive diffraction users and users of the NSLS TXM.

NSLS-II Controls Program-PSHA

The NSLS-II Controls Program is responsible for the installation, operation, and management of all computer and motion controls, networking and information technology resources, and diagnostics and control systems for all NSLS-II accelerator and beamline facilities.

Accelerator Controls-PSHB

The accelerator controls group builds and maintains the application program system, the control system core, which includes all middle layer services and high level applications, the control system Ethernet distribution system, and the frontend computer hard and software interfaces to the accelerator components. The border of responsibility between control system and accelerator subsystem owner varies from hardware system to hardware system. The control system also operates and maintains the timing system, as well as the deterministic data connection between accelerator components around the ring which enables feedback and equipment protection functionality. The control system also supports general services such as alarm functions, data logging and operational electronic logbooks.

The group is responsible for implementing, maintaining and improving the operations interfaces to all accelerator subsystems. This team also assumes the responsibility for keeping the controls system up for beam operations seven days a week, 24 hours a day. All technical support stems from this team for the installation of new machine and beam lines.

Motion Control-PSHC

This group is responsible for control of beamline motor systems and actuators.

DAQ & Computing Group-PSHD

Group dedicated to designing and implementing the NSLS-II data collection architecture. Group has responsibilities that extend from data collection & scanning through the storage of all experimental data both local at the beamline and at the central data center prototype and ultimately to Central Institutional facilities at BNL as necessary. Scanning and analysis workflows are developed in collaboration with beamline scientists.

IT Infrastructure Group - PSHE

The IT Infrastructure Group is responsible for development and maintenance of all Facility Computing & Data Storage Infrastructure, development and maintenance of all Facility IT and Network Infrastructure, and sysadmin functions for the facility.

Controls Infrastructure (EPS)-PSHF

This group is responsible for beamline equipment protection systems, including design, software implementation, integration, testing, and operations of PLC-based equipment protection.

Controls Infrastructure-PSHG

This group supports development of beamline EPS systems as well as support in cabling and wiring for new beamlines. The group maintains controls cabling and wiring systems for the accelerator controls and for controls networking.

Beamline Controls – PSHH

This group is responsible for developing controls for new beam line projects and operating beamlines. The scope of beam line project controls work includes development of controls for beam line components (mirrors, monochromators, experimental end stations, material handling systems, equipment protection systems) and development of data acquisition systems and sample control for all beam lines. The group is also responsible for control of beamline motor systems, detectors, beamline and endstation diagnostics and actuators. This team also develops the operations interface to beam line components and works with the operations team and beam line scientists to define and develop local and central control room interfaces to operate the beam lines. This group provides support for new beamline projects, and provides support for operating beamlines.

e. Summary table indicating job category and fraction of support by staff

Provided below is the summary table indicating the job category and fraction of support for each staff during FY16. This table can also be found on the review website under Required Documents & Spreadsheets.

Name	Category*	Organization Unit**	BES Operation for regular function (FTE)	BES Operation for beamline development (FTE)	NEXT (FTE)	Overhead (FTE)	LDRD	Others non-BES (FTE)	Total (FTE)
HANSON,MARY	ADMIN	**PSAA**	0.00	0.00	0.00	0.96	0.00	0.09	1.05
MARSHALL,JOAN	ADMIN	**PSAA**	0.00	0.00	0.00	1.01	0.00	0.00	1.01
MCGEE,LEISA	ADMIN	**PSAA**	0.00	0.00	0.00	0.41	0.00	0.00	0.41
MILLER,LAURA	ADMIN	**PSAA**	0.00	0.00	0.00	0.00	0.00	0.47	0.47
SHAW,DANA	ADMIN	**PSAA**	0.00	0.00	0.00	0.37	0.00	0.00	0.37
STEIN,TAMMY	ADMIN	**PSAA**	0.35	0.00	0.00	0.01	0.00	0.41	0.76
BEBON,MICHAEL	MGMT	**PSAA**	0.26	0.00	0.00	0.60	0.00	0.19	1.04
HILL,JOHN	MGMT	**PSAA**	0.00	0.00	0.00	0.00	0.00	1.02	1.02
JOHNSON,ERIK	MGMT	**PSAA**	0.74	0.00	0.00	0.00	0.00	0.24	0.98
SHEN,QUN	MGMT	**PSAA**	0.00	0.00	0.00	0.74	0.00	0.25	0.98
MADONIA,CHRISTINE	ADMIN	PSAA-DI	0.01	0.01	0.02	0.98	0.00	0.00	1.02
WILLIAMS,JOANN	ADMIN	PSAA-PECC	0.00	0.00	0.00	0.77	0.00	0.00	0.77
BOBISDELONG,MARVE	ADMIN	**PSAB**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
CORWIN,MARYANNE	ADMIN	**PSAB**	0.10	0.00	0.00	0.39	0.00	0.00	0.49
LEIGHLEY,TABATHA	ADMIN	**PSAB**	0.21	0.00	0.00	0.00	0.00	0.00	0.21
SHOEMAKERSKOKOV,ASHLEY	ADMIN	**PSAB**	0.49	0.00	0.00	0.16	0.00	0.00	0.65
LEE,ROBERT	MGMT	**PSAB**	0.98	0.00	0.00	0.00	0.00	0.00	0.98
KISS,ROBERT	TECH	**PSAB**	0.00	0.00	0.00	0.00	0.00	0.12	0.12
MENDEZ,JOSE	TECH	**PSAB**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
ROBINSON,REGINA	TECH	**PSAB**	0.99	0.00	0.00	0.00	0.00	0.00	0.99
BAUER,DEBORAH	PROF	PSAB-ESAE	0.26	0.00	0.00	0.00	0.00	0.00	0.26
LEIN,BRUCE	PROF	PSAB-HPAE	1.03	0.00	0.00	0.00	0.00	0.00	1.03
WEILANDICS,CHRISTOPHER	PROF	PSAB-HPAH	0.32	0.00	0.00	0.00	0.00	0.00	0.32
ACKERMAN,ANDREW	PROF	PSAB-HPCE	0.47	0.17	0.25	0.00	0.00	0.12	1.02
CHMIEL,ROBERT	PROF	PSAB-HPCE	1.03	0.00	0.00	0.00	0.00	0.00	1.03
HENEVELD,BRIAN	PROF	PSAB-HPCE	1.02	0.00	0.00	0.00	0.00	0.00	1.02
MCDONALD,THOMAS	PROF	PSAB-HPCE	0.99	0.00	0.00	0.00	0.00	0.00	0.99
STIEGLER,LORI	PROF	PSAB-HPCE	0.42	0.30	0.19	0.00	0.00	0.05	0.97
STUVE,GABRIELLE	PROF	PSAB-HPCE	0.99	0.00	0.00	0.00	0.00	0.00	0.99
CHESWICKJR,EDWARD	PROF	PSAB-PQQA	0.00	0.00	0.00	1.07	0.00	0.00	1.07
HAWKES,JAMES	PROF	PSAB-PQQA	0.96	0.00	0.07	0.00	0.00	0.00	1.03
ODINMCCABE,JEAN	PROF	PSAB-PQQA	0.17	0.00	0.00	0.00	0.00	0.00	0.17
PORRETTO,CHRISTOPHER	PROF	PSAB-PQQA	0.00	0.00	0.00	1.03	0.00	0.00	1.03
ZIPPER,JOSEPH	PROF	PSAB-PQQA	0.01	0.41	0.51	0.00	0.00	0.09	1.03
GHOSH,VINITA	SCI	PSAB-RPAA	0.18	0.05	0.34	0.00	0.00	0.08	0.65
MOSS,STEVEN	PROF	PSAB-RPAF	0.99	0.00	0.00	0.00	0.00	0.00	0.99
BENMERROUCHE,MOHAMED	SCI	PSAB-RPAF	0.69	0.21	0.13	0.00	0.00	0.01	1.04
WHYTE,CHELSEA	ADMIN	PSAC-PAAA	-0.05	0.00	0.00	0.56	0.00	0.00	0.51
KISS,SONYA	ADMIN	**PSAD**	0.05	0.00	0.00	0.00	0.00	0.05	0.11
MORELLO,EILEEN	ADMIN	**PSAD**	0.00	0.34	0.42	0.00	0.00	0.20	0.96
ADAMS,JULIAN	MGMT	**PSAD**	0.03	0.94	0.00	0.00	0.00	0.10	1.08
BERMAN,LONNY	MGMT	**PSAD**	0.00	0.20	0.00	0.00	0.00	0.83	1.03
BROADBENT,ANDREW	MGMT	**PSAD**	0.00	1.03	0.00	0.00	0.00	0.00	1.03
HULBERT,STEVEN	MGMT	**PSAD**	0.00	0.00	0.98	0.00	0.00	0.00	0.98
KEISTER,JEFFREY	SCI	**PSAD**	0.00	0.00	1.04	0.00	0.00	0.00	1.04
MOEBES,BARBARA	ADMIN	**PSBA**	0.99	0.00	0.00	0.00	0.00	0.00	0.99
VERBEECK,LINDA	ADMIN	**PSBA**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
WILLEKE,FERDINAND	MGMT	**PSBA**	0.68	0.00	0.00	0.23	0.01	0.11	1.03
FRIES,GREGORY	PROF	**PSBA**	0.35	0.33	0.09	0.00	0.00	0.27	1.04
BLUM,ERIC	SCIEN	**PSBA**	0.38	0.00	0.00	0.00	0.00	0.00	0.38
HSEUH,HSIAOCHAUN	SCIEN	**PSBA**	0.72	0.00	0.00	0.00	0.00	0.04	0.76
SHAFTAN,TIMUR	SCIEN	**PSBA**	0.59	0.00	0.00	0.40	0.04	0.03	1.06
HE,AN	PROF	**PSBB**	0.00	0.00	0.00	0.00	0.61	0.00	0.61
BASSI,GABRIELE	SCIEN	**PSBB**	0.80	0.00	0.00	0.00	0.26	0.00	1.06
BLEDNYKH,ALEXEI	SCIEN	**PSBB**	0.89	0.00	0.00	0.00	0.00	0.05	0.95
GUO,WEIMING	SCIEN	**PSBB**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
PODOBEDOV,BORIS	SCIEN	**PSBB**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
SELETSKIY,SERGEI	SCIEN	**PSBB**	0.22	0.00	0.00	0.00	0.00	0.00	0.22
SMALYUK,VICTOR	SCIEN	**PSBB**	0.94	0.00	0.00	0.00	0.13	0.00	1.08
YANG,LINGYUN	SCIEN	**PSBB**	0.57	0.00	0.00	0.00	0.00	0.00	0.57
YANG,XI	SCIEN	**PSBB**	0.90	0.12	0.00	0.00	0.00	0.00	1.01
YU,LIHUA	SCIEN	**PSBB**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
CAPPADORO,PETER	PROF	**PSBC**	0.25	0.24	0.23	0.00	0.00	0.31	1.03
FERNANDES,HUSTON	PROF	**PSBC**	0.26	0.48	0.14	0.00	0.00	0.13	1.01
HARDER,DAVID	PROF	**PSBC**	0.78	0.19	0.04	0.00	0.00	0.00	1.01
MUSARDO,MARCO	PROF	**PSBC**	0.27	0.43	0.30	0.00	0.00	0.04	1.04
RANK,JAMES	PROF	**PSBC**	0.21	0.47	0.10	0.00	0.00	0.21	0.99
HIDAKA,YOSHITERU	SCIEN	**PSBC**	0.96	0.04	0.01	0.00	0.01	0.00	1.01
HIDAS,DEAN	SCIEN	**PSBC**	0.69	0.30	0.07	0.00	0.00	0.01	1.07
KITEGI,CHARLES	SCIEN	**PSBC**	0.37	0.09	0.55	0.00	0.00	0.04	1.04
TANABE,TOSHIYA	SCIEN	**PSBC**	0.73	0.20	0.02	0.00	0.00	0.12	1.06
CORWIN,TODD	TECH	**PSBC**	0.19	0.05	0.01	0.00	0.00	0.00	0.25
LICCIARDI,WILLIAM	TECH	**PSBC**	0.64	0.23	0.09	0.00	0.00	0.04	1.01
RHEIN,CRAIG	TECH	**PSBC**	0.39	0.42	0.08	0.00	0.00	0.16	1.05
GAO,FENG	PROF	**PSBD**	1.03	0.00	0.00	0.00	0.00	0.03	1.06
HOLUB,BRIAN	PROF	**PSBD**	1.06	0.00	0.00	0.00	0.00	0.00	1.06
KULPIN,JOHN	PROF	**PSBD**	0.10	0.00	0.00	0.00	0.00	0.00	0.10
MARQUES,CARLOS	PROF	**PSBD**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
ROSE,JAMES	PROF	**PSBD**	1.02	0.00	0.00	0.00	0.00	0.01	1.03
CUPOLO,JOHN	TECH	**PSBD**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
DAVILA,PETER	TECH	**PSBD**	0.99	0.00	0.00	0.00	0.00	0.00	0.99
MCDONALD,KEITH	TECH	**PSBD**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
OLIVA,JORGE	TECH	**PSBD**	0.93	0.00	0.00	0.00	0.00	0.16	1.09
PAPU,JOSEPH	TECH	**PSBD**	1.08	0.00	0.00	0.00	0.00	0.00	1.08
SIKORA,ROBERT	TECH	**PSBD**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
SORRENTINO,CHRISTOPHER	TECH	**PSBD**	1.05	0.00	0.00	0.00	0.00	0.02	1.07
BACHA,BELKACEM	PROF	**PSBE**	0.98	0.03	0.00	0.00	0.00	0.01	1.02
CARACAPPA,ANTHONY	PROF	**PSBE**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
DELLAPENNAJR,ALFRED	PROF	**PSBE**	0.87	0.04	0.00	0.00	0.00	0.11	1.02
KOSCIUK,BERNARD	PROF	**PSBE**	0.46	0.44	0.00	0.00	0.00	0.13	1.03
PADRAZOJR,DANNY	PROF	**PSBE**	0.56	0.24	0.02	0.00	0.00	0.21	1.03
SINGH,OM	PROF	**PSBE**	0.55	0.00	0.00	0.00	0.00	0.00	0.55
CHENG,WEIXING	SCIEN	**PSBE**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
BORRELLI,ALFONSO	TECH	**PSBE**	0.70	0.08	0.05	0.00	0.00	0.21	1.03
DANNEIL,CHRISTOPHER	TECH	**PSBE**	0.86	0.10	0.03	0.00	0.00	0.04	1.03
MAGGIPINTO,MARSHALL	TECH	**PSBE**	0.83	0.08	0.00	0.00	0.00	0.10	1.02
MUNOZ,ARTURO	TECH	**PSBE**	0.42	0.35	0.04	0.00	0.00	0.20	1.01
RAMBO,WAYNE	TECH	**PSBE**	0.78	0.15	0.01	0.00	0.00	0.07	1.00
TALLENTJR,JACK	TECH	**PSBE**	0.54	0.23	0.04	0.00	0.00	0.14	0.95

Name	Category*	Organization Unit**	BES Operation for regular function (FTE)	BES Operation for beamline development (FTE)	NEXT (FTE)	Overhead (FTE)	LDRD	Others non-BES (FTE)	Total (FTE)
MEAD,JOSEPH	PROF	PSBE- IOPF	0.95	0.00	0.00	0.00	0.00	0.00	0.95
DOOMJR,LEWIS	PROF	**PSBF**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
SMITH,REID	PROF	**PSBF**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
CHOI,JINHYUK	SCIEN	**PSBF**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
LI,YONGJUN	SCIEN	**PSBF**	1.06	0.00	0.00	0.00	0.00	0.00	1.06
WANG,GUIMEI	SCIEN	**PSBF**	0.98	0.00	0.00	0.00	0.06	0.00	1.04
HETZEL,CHARLES	PROF	**PSBG**	0.92	0.03	0.04	0.00	0.00	0.01	0.99
LENG,SHUWEI	PROF	**PSBG**	0.64	0.32	0.00	0.00	0.00	0.09	1.05
TODD,ROBERT	PROF	**PSBG**	0.18	0.10	0.51	0.00	0.00	0.19	0.99
WILSON,KING	PROF	**PSBG**	0.57	0.19	0.00	0.00	0.00	0.24	1.00
ZIGROSSER,DOUGLAS	PROF	**PSBG**	0.85	0.00	0.00	0.00	0.00	0.00	0.85
DEBOER,WALTER	TECH	**PSBG**	0.84	0.10	0.02	0.00	0.00	0.07	1.03
DELAPARRA,CHARLES	TECH	**PSBG**	0.64	0.40	0.15	0.00	0.00	0.21	1.39
DETOLL,PETER	TECH	**PSBG**	0.56	0.26	0.14	0.00	0.00	0.20	1.16
GALIOTO,PETER	TECH	**PSBG**	0.50	0.14	0.02	0.00	0.00	0.01	0.67
GRANDY,JAMES	TECH	**PSBG**	0.42	0.64	0.03	0.00	0.00	0.21	1.31
PALECEKJR,PAUL	TECH	**PSBG**	0.67	0.17	0.03	0.00	0.00	0.13	1.00
STOLFI,JAMES	TECH	**PSBG**	0.40	0.24	0.32	0.00	0.00	0.20	1.16
USACK,VICTOR	TECH	**PSBG**	0.09	0.05	0.07	0.00	0.00	0.00	0.22
FLILLER,RAYMOND	PROF	**PSBJ**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
SUMMERS,TASHA	PROF	**PSBJ**	0.55	0.00	0.00	0.00	0.00	0.00	0.55
ZITVOGEL,EMIL	PROF	**PSBJ**	0.95	0.00	0.00	0.00	0.00	0.00	0.95
DALSACE,ROY	TECH	**PSBJ**	0.13	0.00	0.00	0.00	0.00	0.00	0.13
GARDNER,CHARLES	TECH	**PSBJ**	0.97	0.03	0.24	0.00	0.00	0.01	1.25
HARKINS,ANTHONY	TECH	**PSBJ**	1.14	0.00	0.01	0.00	0.00	0.02	1.17
JEW,WILLIAM	TECH	**PSBJ**	1.10	0.00	0.02	0.00	0.00	0.01	1.14
MARINO,PHILIP	TECH	**PSBJ**	1.13	0.01	0.01	0.00	0.00	-0.01	1.15
MILLER,THOMAS	TECH	**PSBJ**	1.10	0.01	0.01	0.00	0.00	0.01	1.13
OLDHAM,TIMOTHY	TECH	**PSBJ**	1.16	0.03	0.05	0.00	0.00	0.02	1.25
PHARR,LEONARD	TECH	**PSBJ**	1.12	0.00	0.00	0.00	0.00	0.00	1.12
RAINER,ROBERT	TECH	**PSBJ**	1.11	0.00	0.05	0.00	0.00	0.00	1.17
RATZKE,PETER	TECH	**PSBJ**	1.18	0.00	0.01	0.00	0.00	0.01	1.21
SANTANA,MICHAEL	TECH	**PSBJ**	1.08	0.00	0.00	0.00	0.00	0.02	1.11
WEINER,GARY	TECH	**PSBJ**	1.12	0.01	0.00	0.00	0.00	0.00	1.13
ZEITLER,EDWARD	TECH	**PSBJ**	1.13	0.00	0.03	0.00	0.00	0.01	1.16
BERGMAN,DAVID	PROF	**PSBK**	0.91	0.12	0.00	0.00	0.00	0.03	1.06
BOERNERJR,ALBERT	PROF	**PSBK**	0.60	0.20	0.10	0.00	0.00	0.10	0.99
ESCALLIER,JOHN	PROF	**PSBK**	0.25	0.40	0.00	0.00	0.00	0.30	0.94
GANETIS,GEORGE	PROF	**PSBK**	0.68	0.13	0.13	0.00	0.00	0.06	0.99
KLARE,STEVEN	PROF	**PSBK**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
KOWALSKI,STEPHEN	PROF	**PSBK**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
LOUIE,WING	PROF	**PSBK**	0.92	0.06	0.00	0.00	0.00	0.00	0.97
RICCIARDELLI,JOHN	PROF	**PSBK**	0.74	0.08	0.22	0.00	0.00	0.00	1.04
ZUHOSKIJR,PETER	PROF	**PSBK**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
BELL,SCOTT	TECH	**PSBK**	0.53	0.15	0.36	0.00	0.00	0.00	1.05
DEVERY,STEVEN	TECH	**PSBK**	0.18	0.50	0.54	0.00	0.00	0.03	1.24
DIAZ,HENRY	TECH	**PSBK**	0.64	0.33	0.00	0.00	0.00	0.01	0.99
DURFEE,DOUGLAS	TECH	**PSBK**	0.93	0.00	0.10	0.00	0.00	0.01	1.04
FIELITZ,WILLIAM	TECH	**PSBK**	0.18	0.67	0.29	0.00	0.00	0.01	1.16
FULKERSON,MICHAEL	TECH	**PSBK**	0.36	0.12	0.00	0.00	0.00	0.69	1.18
GORMLEY,JOSEPH	TECH	**PSBK**	0.46	0.15	0.50	0.00	0.00	0.01	1.11
LYON,RICHARD	TECH	**PSBK**	0.25	0.81	0.09	0.00	0.00	0.10	1.25
OLDHAM,DANIEL	TECH	**PSBK**	0.82	0.21	0.11	0.00	0.00	0.08	1.22
ORBAN,SCOTT	TECH	**PSBK**	0.44	0.20	0.27	0.00	0.00	0.09	1.00
PEDERSEN,KENNETH	TECH	**PSBK**	0.02	0.00	0.00	0.00	0.00	0.11	0.13
SINGH,POORAN	TECH	**PSBK**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
SUAREZ,LEE	TECH	**PSBK**	0.35	0.55	0.06	0.00	0.00	0.08	1.04
WEIGAND,EDWARD	TECH	**PSBK**	0.26	0.28	0.39	0.00	0.00	0.01	0.94
AMUNDSEN,CHRISTOPHER	PROF	**PSBL**	0.14	0.09	0.00	0.00	0.00	0.80	1.03
BREITFELLER,MARK	PROF	**PSBL**	0.49	0.30	0.03	0.00	0.00	0.24	1.07
DEPAOLA,FRANK	PROF	**PSBL**	0.12	0.37	0.00	0.00	0.00	0.55	1.03
SHARMA,SUSHIL	PROF	**PSBL**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
SPATARO,CHARLES	PROF	**PSBL**	0.65	0.01	0.00	0.00	0.00	0.31	0.97
APARICIO,GUILLERMO	TECH	**PSBL**	0.33	0.44	0.16	0.00	0.01	0.12	1.06
DACOS,GEORGE	TECH	**PSBL**	0.04	0.67	0.00	0.00	0.00	0.35	1.07
DUFFJR,JEFFREY	TECH	**PSBL**	0.05	0.57	0.00	0.00	0.00	0.39	1.01
LINCOLN,FRANK	TECH	**PSBL**	0.13	0.56	0.00	0.00	0.00	0.32	1.00
LOFFREDO,RONALD	TECH	**PSBL**	0.00	0.00	0.00	0.00	0.00	0.06	0.06
MAGILLIII,JAMES	TECH	**PSBL**	0.05	0.00	0.17	0.00	0.00	0.80	1.02
MCCAFFREYJR,JOHN	TECH	**PSBL**	0.35	0.52	0.04	0.00	0.00	0.18	1.10
NEWBURGH,WILLIAM	TECH	**PSBL**	0.26	0.31	0.25	0.00	0.00	0.14	0.96
PAPPAS,GARY	TECH	**PSBL**	0.41	0.28	0.30	0.00	0.00	0.13	1.13
PULEO,DANNY	TECH	**PSBL**	0.00	0.01	0.00	0.00	0.00	0.39	0.40
SCHEUERER,ROBERT	TECH	**PSBL**	0.49	0.27	0.02	0.00	0.00	0.14	0.92
WALSH,BRIAN	TECH	**PSBL**	0.47	0.46	0.04	0.00	0.00	0.14	1.12
GASH,WILLIAM	PROF	**PSBM**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
GOSMAN,JOHN	PROF	**PSBM**	0.94	0.02	0.05	0.00	0.00	0.01	1.03
OBRIEN,WILLIAM	PROF	**PSBM**	0.44	0.18	0.13	0.00	0.00	0.20	0.96
ROSE,BENJAMIN	PROF	**PSBM**	1.08	0.00	0.00	0.00	0.00	0.00	1.08
SITNIKOV,ALEXANDRE	PROF	**PSBM**	1.12	0.00	0.00	0.00	0.00	0.00	1.12
ALMOND,JOHN	TECH	**PSBM**	0.97	0.09	0.03	0.00	0.00	0.01	1.10
BARONE,STEPHEN	TECH	**PSBM**	0.00	0.43	0.00	0.00	0.00	0.13	0.55
BRIGUCCIA,VINCENT	TECH	**PSBM**	0.45	0.15	0.17	0.00	0.00	0.40	1.17
DILGEN,THOMAS	TECH	**PSBM**	0.99	0.00	0.00	0.00	0.00	0.00	1.00
IACCARINO,RICHARD	TECH	**PSBM**	0.73	0.10	0.03	0.00	0.00	0.12	0.98
RISI,NICHOLAS	TECH	**PSBM**	0.28	0.00	0.00	0.00	0.00	0.01	0.29
RIVERA,PEDRO	TECH	**PSBM**	0.07	0.37	0.07	0.00	0.00	0.56	1.07
SANTANGELO,LEONARD	TECH	**PSBM**	0.29	0.27	0.05	0.00	0.00	0.38	0.98
SCHWARZ,MICHAEL	TECH	**PSBM**	0.00	0.39	0.00	0.00	0.00	0.12	0.51
THEMANN,WILLIAM	TECH	**PSBM**	0.55	0.22	0.11	0.00	0.00	0.13	1.02
BUDA,SCOTT	PROF	**PSBN**	0.30	0.41	0.24	0.00	0.00	0.07	1.02
CASTIBLANCO,ANDRES	PROF	**PSBN**	0.41	0.40	0.13	0.00	0.00	0.11	1.05
ORR,EWART	PROF	**PSBN**	0.28	0.29	0.37	0.00	0.00	0.09	1.03
XIN,SUSHENG	PROF	**PSBN**	0.19	0.31	0.40	0.00	0.00	0.14	1.04
ALLEN,ELLIOT	TECH	**PSBN**	0.09	0.57	0.66	0.00	0.00	0.06	1.38
GALLAGHER,JOHN	TECH	**PSBN**	0.41	0.26	0.26	0.00	0.00	0.07	1.00
GOLDBAUM,RUSSELL	TECH	**PSBN**	0.21	0.44	0.68	0.00	0.00	0.03	1.36
SANTIAGO,ANTHONY	TECH	**PSBN**	0.52	0.15	0.27	0.00	0.00	0.05	0.99
STIVALA,MICHAEL	TECH	**PSBN**	0.25	0.32	0.50	0.00	0.00	0.05	1.12
SAUERWALD,ANDREW	TECH	PSBN-AMDA	0.14	0.44	0.58	0.00	0.00	0.03	1.18

Name	Category*	Organization Unit**	BES Operation for regular function (FTE)	BES Operation for beamline development (FTE)	NEXT (FTE)	Overhead (FTE)	LDRD	Others non-BES (FTE)	Total (FTE)
BOHENEK,JOHN	TECH	**PSBO**	0.38	0.22	0.06	0.00	0.00	0.11	0.77
JARZABKOWSKI,STEVEN	TECH	**PSBO**	0.55	0.22	0.31	0.00	0.00	0.10	1.18
MALLEYJR,JEROME	TECH	**PSBO**	0.46	0.17	0.27	0.00	0.00	0.09	0.99
ORBAN,SCOTT	TECH	**PSBO**	0.07	0.01	0.03	0.00	0.00	0.00	0.11
PFEFFER,MARC	TECH	**PSBO**	0.75	0.05	0.31	0.00	0.00	0.04	1.15
AMARITO,CHARLES	TECH	**PSBP**	0.09	0.36	0.09	0.00	0.00	0.02	0.56
DESANTIS,ANDREW	TECH	**PSBP**	1.01	0.13	0.00	0.00	0.00	0.01	1.15
FABIJANIC,JOHN	TECH	**PSBP**	0.00	0.02	0.00	0.00	0.00	1.01	1.03
FAUSSETE,RICHARD	TECH	**PSBP**	0.27	0.46	0.01	0.00	0.00	0.27	1.01
GAMBELLA,RICHARD	TECH	**PSBP**	0.18	0.50	0.02	0.00	0.07	0.32	1.09
JOHANSON,MICHAEL	TECH	**PSBP**	0.07	0.99	0.00	0.00	0.00	0.00	1.06
KING,AMANDA	TECH	**PSBP**	0.00	0.00	1.00	0.00	0.00	0.00	1.00
LOFTUS,MICHAEL	TECH	**PSBP**	0.16	0.69	0.19	0.00	0.00	0.06	1.10
LONGO,CYNTHIA	TECH	**PSBP**	0.01	0.09	0.89	0.00	0.00	0.00	0.99
MULLANY,BRIAN	TECH	**PSBP**	0.18	0.55	0.11	0.00	0.00	0.21	1.05
PJEROV,SLOBODAN	TECH	**PSBP**	0.00	0.00	0.89	0.00	0.00	0.11	1.00
REFFI,LEO	TECH	**PSBP**	0.31	0.11	0.07	0.00	0.00	0.58	1.07
STELMACH,CHRISTOPHER	TECH	**PSBP**	0.32	0.37	0.28	0.00	0.04	0.09	1.10
TUOZZOLO,JOHN	TECH	**PSBP**	0.12	0.38	0.00	0.00	0.00	0.54	1.04
WILDS,WILLIAM	TECH	**PSBP**	0.12	0.85	0.00	0.00	0.00	0.04	1.01
YU,CHENGHAO	PROF	**PSBQ**	0.97	0.02	0.04	0.00	0.00	0.01	1.04
DAVIS,DONALD	TECH	**PSBQ**	0.19	0.25	0.46	0.00	0.00	0.27	1.17
HUBBARDJR,RODGER	TECH	**PSBQ**	0.23	0.21	0.24	0.00	0.00	0.36	1.04
PALLADINO,MATTHEW	TECH	**PSBQ**	0.32	0.03	0.08	0.00	0.00	0.56	0.99
KARL,FRANCIS	PROF	PSBQ-ADEC	0.20	0.00	0.00	0.00	0.00	0.00	0.20
ILARDO,MATTHEW	PROF	PSBQ-ADEI	0.00	0.00	0.03	0.00	0.00	0.03	0.07
KE,MING	PROF	PSBQ-ADEI	0.06	0.21	0.30	0.00	0.00	0.21	0.77
BOWDEN,ANGELA	ADMIN	**PSEA**	0.02	0.00	0.00	0.00	0.00	0.00	0.02
MALDONADO,SUSAN	ADMIN	**PSEA**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
SMILES,JEAN	ADMIN	**PSEA**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
ZSCHACK,PAUL	MGMT	**PSEA**	0.78	0.00	0.00	0.25	0.00	0.00	1.03
OCKO,BENJAMIN	SCI	**PSEA**	0.89	0.10	0.00	0.00	0.00	0.00	1.00
BOLMATOV,DMITRY	POST DOC	**PSEB**	0.00	0.00	0.00	0.11	0.98	0.00	1.09
ZHANG,YUGANG	PROF	**PSEB**	1.09	0.00	0.00	0.00	0.00	0.00	1.09
CUNSOLO,ALESSANDRO	SCI	**PSEB**	1.06	0.00	0.00	0.00	0.00	0.00	1.06
DIMASI,ELAINE	SCI	**PSEB**	0.00	0.00	1.04	0.00	0.00	0.00	1.04
FLUERASU,ANDREI	SCI	**PSEB**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
FUKUTO,MASAFUMI	SCI	**PSEB**	0.07	0.98	0.00	0.00	0.00	0.00	1.05
PINDAK,RONALD	SCI	**PSEB**	0.94	0.00	0.00	0.10	0.00	0.00	1.04
SUVOROV,ALEXEY	SCI	**PSEB**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
WIEGART,LUTZ	SCI	**PSEB**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
ZHERNENKOV,MIKHAIL	SCI	**PSEB**	0.00	0.00	1.02	0.00	0.00	0.00	1.02
GREENE,RICHARD	TECH	**PSEB**	0.51	0.36	0.38	0.00	0.00	0.00	1.26
HU,WEN	POST DOC	**PSED**	0.15	0.00	0.00	0.07	0.62	0.00	0.84
SHI,YINGBO	POST DOC	**PSED**	0.00	0.00	0.58	0.00	0.00	0.00	0.58
BARBOUR,ANDI	PROF	**PSED**	1.11	0.00	0.00	0.00	0.00	0.00	1.11
HUNT,ADRIAN	PROF	**PSED**	0.50	0.00	0.00	0.00	0.00	0.00	0.50
BISOGNI,VALENTINA	SCI	**PSED**	0.00	0.00	1.07	0.00	0.00	0.00	1.07
CARR,G	SCI	**PSED**	0.56	0.46	0.00	0.00	0.00	0.00	1.02
DVORAK,JOSEPH	SCI	**PSED**	0.02	0.17	0.84	0.00	0.00	0.00	1.04
JARRIGE,IGNACE	SCI	**PSED**	0.00	0.08	0.99	0.00	0.00	0.00	1.07
MAZZOLI,CLAUDIO	SCI	**PSED**	1.08	0.00	0.00	0.00	0.00	0.00	1.08
VESCOVO,ELIO	SCI	**PSED**	0.17	0.00	0.91	0.00	0.00	0.00	1.08
WALTER,ANDREW	SCI	**PSED**	0.16	0.00	0.94	0.00	0.00	0.00	1.10
WALUYO,IRADWIKANARI	SCI	**PSED**	1.10	0.00	0.00	0.00	0.00	0.00	1.10
WILKINS,STUART	SCI	**PSED**	0.88	0.00	0.00	0.09	0.00	0.00	0.97
FARERIA,LARRY	TECH	**PSED**	0.44	0.00	0.96	0.00	0.00	0.00	1.39
REICHEL,AMY	PROF	**PSEE**	0.00	0.00	0.00	0.00	0.00	0.02	0.02
CAI,YONG	SCI	**PSEE**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
QUETZ,ABDIEL	PROF	**PSEF**	0.00	0.00	0.00	0.00	0.00	0.22	0.22
TUTUNCU,GOKNUR	POST DOC	**PSEG**	0.00	0.00	0.00	0.00	0.03	0.00	0.03
BAI,JIANMING	PROF	**PSEG**	0.96	0.00	0.00	0.00	0.00	0.06	1.02
ABEYKOON,AM	SCI	**PSEG**	0.72	0.30	0.00	0.00	0.00	0.00	1.03
DOORYHEE,ERIC	SCI	**PSEG**	0.98	0.04	0.00	0.02	0.00	0.00	1.04
EVANSLUTTERODT,KENNETH	SCI	**PSEG**	0.11	0.00	0.93	0.00	0.00	0.00	1.03
GHOSE,SANJIT	SCI	**PSEG**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
NELSON,CHRISTIE	SCI	**PSEG**	0.10	0.00	0.93	0.00	0.00	0.00	1.02
ZHONG,ZHONG	SCI	**PSEG**	0.00	0.91	0.00	0.00	0.00	0.12	1.03
TRUNK,JOHN	TECH	**PSEG**	0.73	0.00	0.33	0.00	0.00	0.00	1.06
LOWERY,ADAM	ADMIN	**PSEH**	0.00	0.00	0.00	0.00	0.00	0.22	0.22
GE,MINGYUAN	POST DOC	**PSEH**	0.00	0.00	0.00	0.11	0.98	0.00	1.09
OZTURK,HANDE	POST DOC	**PSEH**	0.00	0.00	0.00	0.04	0.34	0.00	0.38
ILINSKI,PETR	PROF	**PSEH**	0.78	0.00	0.00	0.00	0.00	0.00	0.78
KALBFLEISCH,SEBASTIAN	PROF	**PSEH**	0.27	0.00	0.00	0.00	0.00	0.00	0.27
CHENWIEGART,YUCHEN	SCI	**PSEH**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
CHU,YONG	SCI	**PSEH**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
HUANG,XIAOJING	SCI	**PSEH**	1.05	0.00	0.00	0.00	0.00	0.00	1.05
LEE,WAHKEAT	SCI	**PSEH**	0.00	1.01	0.00	0.00	0.00	0.00	1.01
MILLER,LISA	SCI	**PSEH**	0.96	0.00	0.00	0.11	0.00	0.00	1.07
TAPPERO,RYAN	SCI	**PSEH**	0.01	0.96	0.00	0.00	0.00	0.00	0.96
THIEME,JUERGEN	SCI	**PSEH**	1.00	0.02	0.00	0.00	0.00	0.00	1.02
WILLIAMS,GARTH	SCI	**PSEH**	1.01	0.06	0.00	0.00	0.00	0.00	1.08
YAN,HANFEI	SCI	**PSEH**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
BIANCAROSA,JAMES	TECH	**PSEH**	0.97	0.48	0.16	0.00	0.00	0.13	1.74
ACEVEDOESTEVES,RAUL	POST DOC	**PSEI**	0.07	0.00	0.00	0.02	0.00	0.09	0.18
ATTENKOFER,KLAUS	SCI	**PSEI**	0.15	0.00	0.62	0.09	0.00	0.19	1.05
EHRLICH,STEVEN	SCI	**PSEI**	0.00	1.01	0.00	0.00	0.00	0.00	1.01
NORTHRUP,PAUL	SCI	**PSEI**	0.07	0.94	0.00	0.00	0.00	0.00	1.01
STAVITSKI,ILYA	SCI	**PSEI**	0.14	0.00	0.93	0.00	0.00	0.00	1.07
NINTZEL,GARY	TECH	**PSEI**	0.00	0.30	0.65	0.00	0.00	0.00	0.95
BAEZ,MERCY	ADMIN	**PSEO**	1.10	0.00	0.00	0.00	0.00	0.00	1.10
CISCO,GRETCHEN	ADMIN	**PSEO**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
MCKENZIE,GLADYS	ADMIN	**PSEO**	1.06	0.00	0.00	0.00	0.00	0.00	1.06
MESSANA,CORINNE	ADMIN	**PSEO**	0.05	0.00	0.00	0.00	0.00	0.00	0.05
WRIGHT,NANCYE	ADMIN	**PSEO**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
WANG,JIAJUN	PROF	**PSEO**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
ROBINSON,HOWARD	SCI	**PSEO**	0.00	0.67	0.00	0.00	0.00	0.33	1.00
WANG,JUN	SCI	**PSEO**	0.98	0.00	0.00	0.00	0.00	0.00	0.98

Name	Category*	Organization Unit**	BES Operation for regular function (FTE)	BES Operation for beamline development (FTE)	NEXT (FTE)	Overhead (FTE)	LDRD	Others non-BES (FTE)	Total (FTE)
BROMFIELD,MICHAEL	PROF	**PSEP**	0.43	0.02	0.43	0.00	0.00	0.09	0.97
BUCKLEY,MICHAEL	PROF	**PSEP**	0.83	0.04	0.10	0.00	0.00	0.02	1.00
DONG,QINGYI	PROF	**PSEP**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
KHALID,SYED	PROF	**PSEP**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
LAMARRA,STEVEN	PROF	**PSEP**	0.88	0.03	0.00	0.00	0.00	0.07	0.99
SHERWOOD,STEPHEN	PROF	**PSEP**	0.28	0.31	0.32	0.00	0.00	0.12	1.03
SMITH,RANDY	PROF	**PSEP**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
STEBBINS,CHRISTOPHER	PROF	**PSEP**	0.03	0.03	0.05	0.00	0.00	0.12	0.23
RAKITIN,MAKSIM	POST DOC	**PSER**	0.00	0.00	0.00	0.08	0.00	0.76	0.84
TCHOUBAR,OLEG	SCI	**PSER**	0.93	0.01	0.00	0.00	0.00	0.05	0.99
MAKLARY,MICHAEL	TECH	**PSER**	0.89	0.34	0.20	0.00	0.00	0.12	1.55
HUANG,LEI	POST DOC	**PSET**	0.71	0.00	0.00	0.10	0.21	0.00	1.02
XU,WEIHE	POST DOC	**PSET**	0.94	0.00	0.00	0.05	0.00	0.00	0.99
KAZNATCHEEV,KONSTANTINE	PROF	**PSET**	0.96	0.10	0.00	0.00	0.00	0.00	1.05
QIAN,SHINAN	PROF	**PSET**	0.00	0.39	0.51	0.00	0.00	0.09	0.99
ZHOU,JUAN	PROF	**PSET**	0.96	0.00	0.00	0.00	0.00	0.00	0.96
BOUET,NATHALIE	SCI	**PSET**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
IDIR,MOURAD	SCI	**PSET**	1.08	0.00	0.00	0.00	0.00	0.00	1.08
NAZARETSKI,EVGENY	SCI	**PSET**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
KUHNE,DENNIS	TECH	**PSET**	1.04	0.00	0.00	0.00	0.00	0.00	1.04
VESCOVI,MATTHEW	TECH	**PSET**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
AZIZ,MDTAREQUE	POST DOC	**PSEU**	0.00	0.00	0.00	0.10	0.00	0.94	1.04
KUCZEWSKI,ANTHONY	PROF	**PSEU**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
MICHTA,RICHARD	PROF	**PSEU**	0.98	0.00	0.00	0.00	0.00	0.00	0.98
RUMAIZ,ABDUL	SCI	**PSEU**	1.02	0.00	0.00	0.00	0.00	0.03	1.06
SIDDONS,DAVID	SCI	**PSEU**	0.98	0.00	0.00	0.00	0.00	0.00	0.98
ANTONELLI,STEPHEN	PROF	**PSEV**	0.55	0.00	0.46	0.00	0.00	0.00	1.02
BACESCU,DANIEL	PROF	**PSEV**	0.19	0.00	0.76	0.00	0.00	0.01	0.96
BHOGADI,DILEEP	PROF	**PSEV**	0.00	0.00	0.00	0.00	0.00	1.01	1.01
CARLUCCIDAYTON,MARY	PROF	**PSEV**	0.90	0.00	0.00	0.00	0.00	0.10	1.00
COBURN,DAVID	PROF	**PSEV**	0.39	0.30	0.32	0.00	0.00	0.00	1.00
DIFABIO,JONATHAN	PROF	**PSEV**	0.01	0.00	0.00	0.00	0.00	1.03	1.05
ENG,CHRISTOPHER	PROF	**PSEV**	0.01	0.00	0.42	0.00	0.65	0.00	1.08
HAAS,EDWIN	PROF	**PSEV**	0.10	0.88	0.02	0.00	0.00	0.03	1.03
LIENHARD,LUKAS	PROF	**PSEV**	0.17	0.92	0.00	0.00	0.00	0.01	1.10
LUCAS,MICHAEL	PROF	**PSEV**	0.21	0.00	0.82	0.00	0.00	0.00	1.03
OHARA,STEVEN	PROF	**PSEV**	0.14	0.33	0.39	0.00	0.00	0.11	0.96
PRICE,ALEXANDER	PROF	**PSEV**	0.00	0.00	0.69	0.00	0.00	0.00	0.70
ZHU,YI	PROF	**PSEV**	0.00	0.00	1.05	0.00	0.00	0.00	1.05
LEONHARDT,WILLIAM	PROF	PSEV- PMDA	0.01	0.04	0.64	0.00	0.00	0.00	0.68
BENNETT,STEVEN	TECH	**PSEW**	0.90	0.03	0.10	0.00	0.00	0.01	1.03
CARLSON,DENNIS	TECH	**PSEW**	0.16	0.03	0.95	0.00	0.00	0.02	1.17
CARUSO,MICHAEL	TECH	**PSEW**	0.06	0.45	0.55	0.00	0.00	0.01	1.06
KOLEDA,CAREY	TECH	**PSEW**	0.21	0.43	0.25	0.00	0.00	0.22	1.11
LEVY,DAVID	TECH	**PSEW**	0.64	0.27	0.16	0.00	0.00	0.00	1.06
MINGINO,ANDREW	TECH	**PSEW**	0.22	0.04	0.95	0.00	0.00	0.02	1.22
STRUBLE,WILLIAM	TECH	**PSEW**	0.10	0.01	1.10	0.00	0.00	0.01	1.23
SULLIVAN,JOSEPH	TECH	**PSEW**	0.66	0.25	0.20	0.00	0.00	0.02	1.12
GAO,YUAN	POST DOC	**PSFE**	0.00	0.00	0.00	0.04	0.38	0.00	0.42
GUO,GONGRUI	POST DOC	**PSFE**	0.00	0.00	0.00	0.04	0.00	0.38	0.42
LIU,WU	POST DOC	**PSFE**	0.00	0.00	0.00	0.05	0.44	0.00	0.49
ANDI,BABAK	PROF	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.05	1.05
GRAZIANO,VITO	PROF	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.08	1.08
LAZO,EDWIN	PROF	**PSFE**	0.00	0.00	0.00	0.00	0.00	0.98	0.98
SHEAMCCARTHY,GRACE	PROF	**PSFE**	0.00	0.00	0.00	0.00	0.00	0.70	0.70
CHODANKAR,SHIRISH	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.09	1.09
FUCHS,MARTIN	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.07	1.07
JAKONCIC,JEAN	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.05	1.05
MCSWEENEY,SEAN	SCI	**PSFE**	0.00	0.00	0.00	0.49	0.00	0.56	1.05
SCHNEIDER,DIETER	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.04	1.04
SOARES,ALEXEI	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.00	1.00
STOJANOFF,VIVIAN	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.07	1.07
SWEET,ROBERT	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	0.82	0.82
YANG,LIN	SCI	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.02	1.02
JACKIMOWICZ,RICHARD	TECH	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.02	1.02
LANGDON,THOMAS	TECH	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.17	1.17
LARA,JOHN	TECH	**PSFE**	0.02	0.00	0.00	0.00	0.00	1.14	1.16
WHALEN,CORNELIUS	TECH	**PSFE**	0.00	0.00	0.00	0.00	0.00	1.07	1.07
FARNSWORTH,RICHARD	PROF	**PSHA**	0.33	0.00	0.00	0.05	0.00	0.00	0.38
SHROFF,KUNAL	PROF	**PSHA**	0.80	0.00	0.00	0.00	0.00	0.06	0.86
BLUM,ERIC	SCI	**PSHA**	0.59	0.00	0.00	0.05	0.00	0.00	0.64
DERBENEV,ANTON	PROF	**PSHB**	1.02	0.00	0.00	0.00	0.00	0.00	1.03
HA,KIMAN	PROF	**PSHB**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
HU,YONG	PROF	**PSHB**	0.97	0.00	0.00	0.00	0.00	0.00	0.97
TAGGER,JUERI	PROF	**PSHB**	1.05	0.00	0.00	0.00	0.00	0.01	1.06
TIAN,YUKE	PROF	**PSHB**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
BASSAN,HARMANPREET	PROF	**PSHC**	0.79	0.09	0.15	0.00	0.00	0.05	1.09
GUERRERO,CHRISTOPHER	PROF	**PSHC**	0.29	0.36	0.00	0.00	0.00	0.01	0.66
TANG,QINGFU	PROF	**PSHC**	0.73	0.21	0.13	0.00	0.00	0.02	1.09
ALLAN,DANIEL	POST DOC	**PSHD**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
ILTIS,GABRIEL	POST DOC	**PSHD**	0.00	0.00	0.00	0.01	0.13	0.00	0.14
LI,LI	POST DOC	**PSHD**	0.87	0.00	0.00	0.08	0.00	0.01	0.96
ARKILIC,ARMAN	PROF	**PSHD**	1.03	0.00	0.00	0.00	0.00	0.00	1.03
CHABOT,DARON	PROF	**PSHD**	0.55	0.00	0.00	0.00	0.00	0.00	0.55
LAUER,KENNETH	PROF	**PSHD**	0.95	0.00	0.00	0.00	0.00	0.00	0.95
MALITSKY,NIKOLAY	PROF	**PSHD**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
TANG,YONGNIAN	PROF	**PSHD**	1.02	0.00	0.00	0.00	0.00	0.00	1.02
CASWELL,THOMAS	SCI	**PSHD**	1.06	0.00	0.00	0.00	0.00	0.00	1.06
DILL,ERIC	SCI	**PSHD**	0.79	0.00	0.00	0.00	0.00	0.00	0.79
HEROUX,ANNIE	SCI	**PSHD**	0.94	0.00	0.00	0.00	0.00	0.07	1.01
COWAN,MATT	PROF	**PSHE**	0.54	0.00	0.00	0.00	0.00	0.45	0.99
FLAKS,LEONID	PROF	**PSHE**	0.42	0.09	0.30	0.00	0.00	0.23	1.03
KARASAWA,MIZUKI	PROF	**PSHE**	1.01	0.00	0.00	0.00	0.00	0.00	1.01
PETKUS,ROBERT	PROF	**PSHE**	0.55	0.12	0.18	0.00	0.00	0.20	1.04
SMITH,THOMAS	PROF	**PSHE**	0.34	0.00	0.00	0.00	0.00	0.00	0.34
SAUTER,STEPHEN	TECH	**PSHE**	0.11	0.14	0.72	0.00	0.00	0.33	1.30
BILELLO,MICHAEL	PROF	**PSHF**	0.04	0.02	0.38	0.00	0.00	0.33	0.76
BISCHOF,GARRETT	PROF	**PSHF**	0.06	0.02	0.00	0.00	0.00	0.00	0.09
CLAY,BARRETT	PROF	**PSHF**	0.38	0.13	0.32	0.00	0.00	0.16	0.98
KADYROV,RUSLAN	PROF	**PSHF**	0.31	0.12	0.38	0.00	0.00	0.23	1.04
DECARO,PHILIP	TECH	**PSHG**	0.18	0.22	0.60	0.00	0.00	0.37	1.36
HARSCH,KENNETH	TECH	**PSHG**	0.31	0.19	0.74	0.00	0.00	0.21	1.44
HERBST,TRAVIS	TECH	**PSHG**	0.25	0.18	0.84	0.00	0.00	0.20	1.48
JANSEN,JOSHUA	TECH	**PSHG**	0.45	0.07	0.33	0.00	0.00	0.07	0.92
KLAUSCHKE,ANDREW	TECH	**PSHG**	0.19	0.15	0.72	0.00	0.00	0.27	1.32
NICOLETTA,MICHAEL	TECH	**PSHG**	0.19	0.07	0.75	0.00	0.00	0.19	1.20
SKELANEY,RICHARD	TECH	**PSHG**	0.39	0.10	0.65	0.00	0.00	0.17	1.31
DEOLIVEIRAOMITTO,DIEGO	PROF	**PSHH**	0.00	0.00	0.35	0.00	0.00	0.20	0.55
DESILVA,LINDAMULAGE	PROF	**PSHH**	0.29	0.35	0.00	0.00	0.00	0.00	0.64
GOFRON,KAZIMIERZ	PROF	**PSHH**	1.00	0.00	0.00	0.00	0.00	0.00	1.00
GUICHARD,NICOLAS	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	0.32	0.32
IVASHKEVYCH,OKSANA	PROF	**PSHH**	0.00	0.55	0.00	0.00	0.00	0.47	1.03
LEWIS,WAYNE	PROF	**PSHH**	0.61	0.03	0.10	0.00	0.00	0.04	0.78
MA,JUN	PROF	**PSHH**	0.00	0.00	1.07	0.00	0.00	0.00	1.07
MYERS,STUART	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	1.01	1.01
QIAN,KUN	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	1.02	1.02
SEIVAMARTINS,BRUNO	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	1.03	1.03
SKINNER,JOHN	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	1.01	1.01
SLEPICKA,HUGO	PROF	**PSHH**	0.00	0.00	0.00	0.00	0.00	1.06	1.06
SO,SUNGLEUNG	PROF	**PSHH**	0.00	0.00	1.03	0.00	0.00	0.00	1.03
VALDRIGHILUVIZOTTO,BRUNO	PROF	**PSHH**	0.60	0.00	0.00	0.00	0.00	0.00	0.60
XU,HUIJUAN	PROF	**PSHH**	0.52	0.11	0.16	0.00	0.00	0.16	0.95
YIN,ZHIJIAN	PROF	**PSHH**	0.16	0.22	0.63	0.00	0.00	0.00	1.02
POSHKA,DENNIS	TECH	**PSHH**	0.30	0.18	0.41	0.00	0.00	0.09	0.98
			212.3	52.3	58.1	11.8	6.0	57.6	398.1

Figure 1.iv.e.1: Summary table indicating job category and fraction of support by staff

1.v Accelerator Operation Milestones Achieved & Beamline Developments

Below we will briefly describe the accelerator operation milestones achieved and beamline developments completed during the review period.

a. Accelerator Operation Milestones Achieved

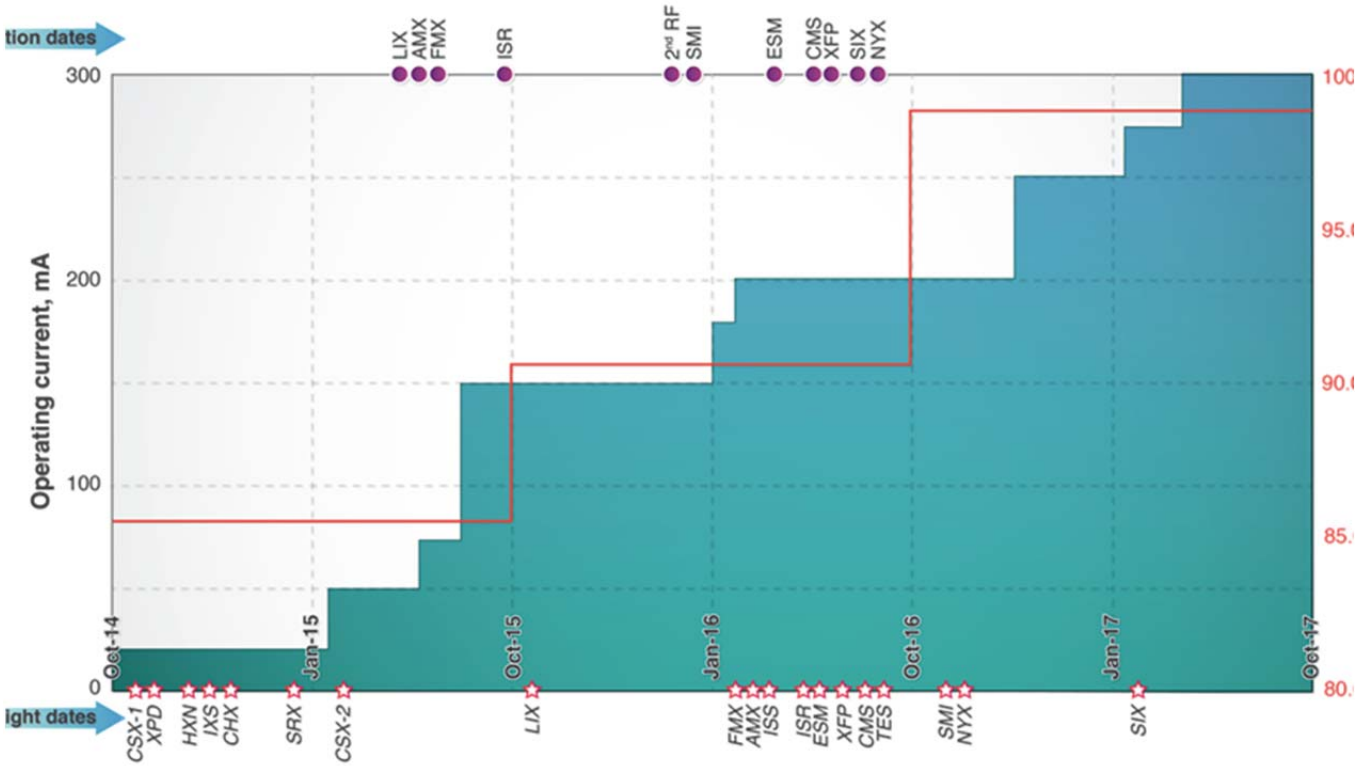

Figure 1.v.a.1: Graph showing ramp up of operating current (green) since the start of operations in October 2014. The red line represents the annual reliability of operations, reference to the right hand scale. The figure for FY17 is YTD. The magenta circles represent installation dates of major components in the storage ring. The stars represent first light dates at the various beamlines.

This section provides a description of accelerator milestones achieved broken out by sub system.

1. ID, FE, beam line developments

Cell Num	ID Name	BL Name	ID Params	ID Install Date	BL 1st Light Date	Project Pkg
C23	EPU-2	CSX-1	2m-EPU49	Aug. 2014	Oct. 2014	Project
C23	EPU-1	CSX-2	2m-EPU49	Aug. 2014	Mar. 2015	Project
C3	IVU	HXN	3m-IVU20	June 2014	Nov. 2014	Project
C5	IVU	SRX	1.5m-IVU21	June 2014	Dec. 2014	Project
C10	IVU	IXS	3m-IVU22	Aug. 2014	Nov. 2014	Project
C11	IVU	CHX	3m-IVU20	June 2014	Nov. 2014	Project
C28	DW	XPD	6.8m-DW100	Oct. 2013	Nov. 2014	Project
C16	IVU	LIX	2.8m-IVU23	May 2015	Nov. 2015	ABBIX
C17	IVU	AMX	1.5m-IVU21	May 2015	Nov. 2015	ABBIX
C17	IVU	FMX	1.5m-IVU21	May 2015	Mar. 2016	ABBIX
C4	IVU	ISR	2.8m-IVU23	Sept. 2015	July 2016	ABBIX
C8	DW	ISS	6.8m-DW100	Dec. 2013	April 2016	NEXT
C12	IVU	SMI	2.8m-IVU23	Dec. 2015	Nov. 2016	NEXT
C21	EPU57	ESM	1.4m-EPU57	May 2016	July 2016	NEXT
C21	EPU105	ESM	2.7m-EPU105	Dec. 2016	None	NEXT
C2	EPU	SIX	3.5m-EPU57	Sept. 2016	Feb. 2017	NEXT
C8	Dipole	TES			Aug. 2016	BDN
C11	3PW	CMS		May 2016	Aug. 2016	BDN
C18	DW	FXI	6.8m-DW100	Jan. 2014	None	BDN
C19	IVU	NYX	1m-IVU18	Sept. 2016	Nov. 2016	Partner
C17	3PW	XFP		May 2016	July 2016	Partner
C18	DW	FXI	6.8m-DW100	Jan. 2014	None	Partner

Table 1.v.a.1: ID, FE Beamline Developments

2. RF developments
   - Post mortem function developed for efficient diagnostics of RF faults and beam dumps in Aug. 2015.
   - New mode of RF / storage ring diagnostics was developed and tested "RF phase jump" in Feb. 2016.
   - 2nd RF cavity was installed in cell 24 in Jan 2016 and subsequently commissioned in Feb.-Mar. 2016.
   - Program on linac klystron upgrade began in Mar. 2016.
   - Speeding up of RF recovery after beam dumps: fast routine on RF start-up and ramp-up established in May 2016.
   - Phase alignment of 1st and 2nd RF cavities accomplished and transferred to operation at high voltage in Sep. 2016.

3. Program reducing root causes of faults and increasing reliability of machine subsystems initiated. Activities included:
   - Ratchet door switches causing PPS system to drop out. Inspected and re-secured all connections on Jan. 2016.
   - Vacuum related beam dumps and gate valve closure in linac and booster; separated ion pumps to work from different controllers within a voting scheme. Completed in Feb. 2016.
   - High radiation alarms downstream of injection straight following beam dump. Added cement block shielding at ratchet doors 01 and 02. Completed in May 2016.
   - Service Building door switches sticking. Added actuator brackets, modified drive angle of levers, and adjusted spacing between doors and switch bodies. Completed on Jun. 2016.
   - Increased lifetime of the booster components and reducing accelerator power consumption. We implemented "sleeping mode of booster operations", which turns large power supplies to low current level between top-off cycles. Program completed on July 2016.
   - RF cavity trips. Implemented periodic partial warmups, repaired vacuum leak at waveguide flange, implemented RF cavity conditioning following each maintenance period starting on Sept. 2016.
   - Vacuum alarm due to argon instability in ion pump in linac wave guide. Replaced leaking RF load in Oct. 2016.
   - Front End shutter EPS/PPS trips. Adjusted all switches and increased over-travel. Implemented periodic inspection. Developed CSS PV to monitor actuation time. Program completed in Dec. 2016.
   - NYX IVU water leak to vacuum. IVU was repaired in Dec 2016 and now is in operations.
   - Frequent trips of booster kickers. New booster injection pulser has been developed based on hot cathode thyrotron technology and tested. First unit has been installed into the kicker 3 position on Jan. 2017.
   - Undefined gate valve closures. Improved CSS engineering screens to allow trouble shooting of gate valves without accessing PLC code in Jan. 2017.
   - High temperature flanges observed during high current beam studies. In Mar. 2017 we identified inadequate RF spring contact between flanges. Inspection and reassembly is in process.
   - Magnet high temperature alarms. Repair Klixon interface boards in process.

4. Active Interlock system for monitoring and interlocking orbit in arcs and Insertion Devices commissioned and improved.
   - AI-BM commissioning complete and the system moved to operations in Oct. 2014.
   - AI-ID added glitch detection logic and glitch filter logic in Jun. 15. The number of BPM-related faults greatly reduced from several times a week to about single event per month.
   - BPM glitch filter added for AI-BM covering multiple BPMs and including canting magnet and photon shutter status in 2016.

- Added enable/disable function for individual Insertion Devices in the global AI system in Jan. 2017.
- Added trigger for filtering AI-ID glitches and AI-BM "crossing zero level" faults in Jan. 2017.
- Change interlock timing for ID photon shutter and BM photon shutter to 1 msec and AI-BM zero error to 2 msec in Jan. 2017. Further reduced frequency of false AI faults.

5. Commence top-off injection in user operations
   - Demonstration of top-off during studies in July 2015.
   - Top-off user operations commenced in Oct. 2015 at 150 mA.
   - Reducing fill time after beam dumps via increasing injection charge rate and optimizing the fill strategy, "Fast fill" initiated in Mar. 2016.
   - Alternative bunch patterns tested during joint studies with beam lines in Mar. 2017.

6. Enabling low vertical emittance mode of operations
   - Demonstration of low vertical emittance at 8 pm rad in Apr. 2015.
   - Demonstration of low vertical emittance at 8 pm rad at high current (275 mA) in Jan. 2017.
   - User Operations with low vertical emittance for a week in Mar. 2017.
   - Commissioning of coupling feedforward table for In-vacuum Undulator AMX using storage ring skew quadrupole correctors in Feb. 2017.

7. Improvements in electron beam orbit stability
   - Demonstration of FOFB operation with closed loop in Mar. 2015.
   - FOFB is transferred to operations in Jun. 2015.
   - Improved suppression of long-term drifts with FOFB in Nov. 2015.
   - Optimized the FOFB by adjusting the gain and eigenmodes. The daily X plane long term drift was reduced from 10um (RMS) to 3um (RMS). The Y plane drift was reduced from 2um (RMS) to 1um (RMS). Please refer to the figures below for a typical BPM.
   - Added capability of angle/offset adjustment for beam line alignment in Jul. 2016.
   - Fast recovery of orbit after beam dump with FOFB in Dec. 2016.
   - Added adjustable weights for ID BPMs to FOFB in Feb. 2017.
   - Efficient shift of fast corrector strength to that of DC correctors in Feb. 2017.
   - Local bump feedforward function is enabled with FOFB operating in Feb. 2017.

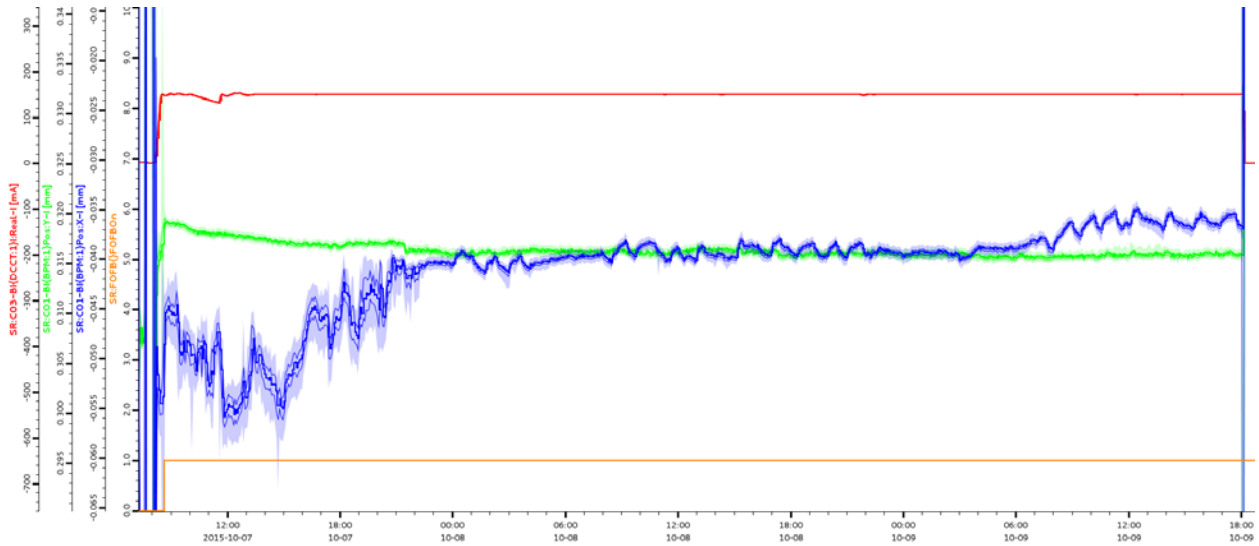

Figure 1.v.a.2: Orbit traces before FOFB optimization. Red line indicates storage ring current, green line indicates orbit position in the vertical plane (50 µm full range of the axis) and the blue line is in the horizontal plane (65 µm full range of the axis) as measured by the C1P1 BPM. The orange line shows status of FOFB system (FOFB is on).

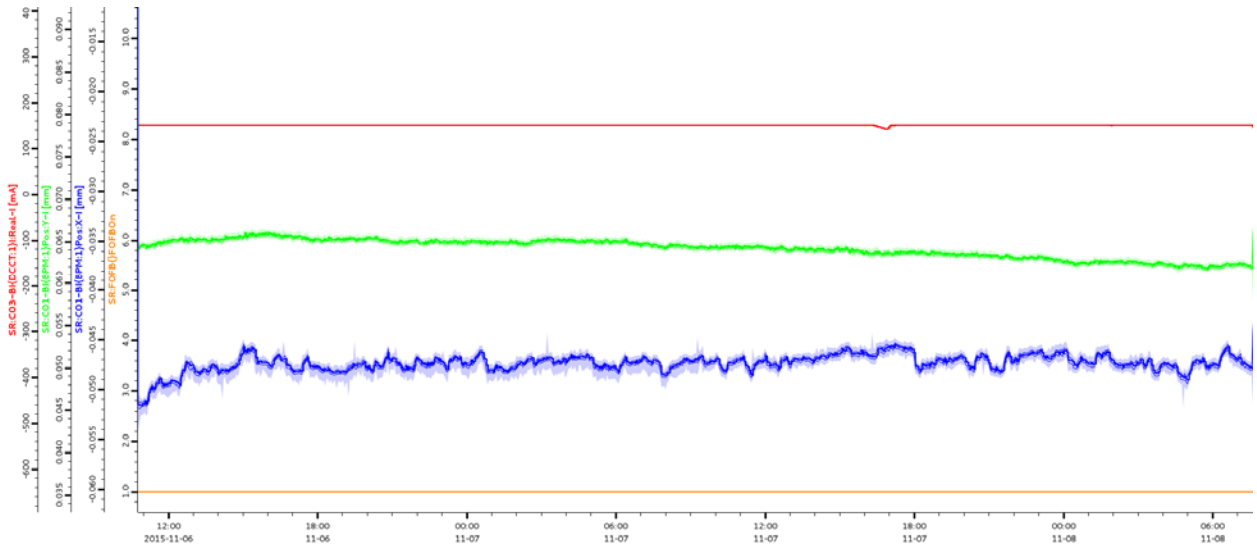

Figure 1.v.a.3: Orbit traces before FOFB optimization. Red line indicates storage ring current, green line indicates orbit position in the vertical plane (25 µm full range of the axis) and the blue line is in the horizontal plane(50 µm full range of the axis) and as measured by the C1P1 BPM. The orange line shows status of FOFB system (FOFB is on).

8. A range of accelerator physics studies have been carried out, including:
   - Development of BPM TbT data for rapid optics and coupling corrections.
   - AC LOCO for precise machine measurement.
   - Demonstration of single-shot tune-amplitude dependence and dynamic aperture measurement using BPM gated TbT data.
   - Generation of local Beta bump in C10 and C16 for Collective Effects Studies.
   - Accurate Impedance Measurements.
   - Demonstration of the nonlinear lattice optimization with square matrix method.
   - Demonstration of the gated BPM function to monitor beam optics transparently.
   - Precise synchronous phase measurement.
   - Improved pin-hole camera by adding vacuum chamber to prevent optical noise induced by air flow.
   - Measured storage ring momentum aperture with RF phase jump in Apr. 2016.
   - Extended studies of crossing half-integer resonance in highly chromatic low-emittance ring lattice from Dec 2015 to June 2016.
   - Demonstration of sextupole alignment technique based on the local bump method.
   - Carried out studies with SR energy reduced to 2.5 GeV for probing ultra-low emittance Touschek lifetime regime.
   - Initiated 100 MeV booster injection studies. The goal is to investigate the reduction of the injection energy to the booster so that the linac can operate with a single klystron, in the event of a klystron failure.

9. Storage ring lattice improvements
   - Linear lattice correction. Before correction, the beta beat exceeded 30%. It has been reduced down to 5-6% after the 1st correction in May 2014.
   - ID integration. Vertical focusing of Damping Wigglers was compensated locally and betatron tune shifts globally corrected in Dec. 2014.
   - Measured horizontal emittance at 1 nm rad with 3 Damping Wigglers in Dec. 2014.
   - ID feedforward tables. Software for automatic generating and validating orbit feedforward tables for IDs has been implemented in Apr. 2015.
   - Vertical beam size minimization. In Apr. 2015 three DWs and three IVUs were closed and vertical dispersion and coupling corrected. The vertical emittance observed with the x-ray pinhole camera was 6pm at 10 mA of beam current. Uncorrected vertical emittance was 26pm.
   - LOCO software package has been tested and released for use in the control room. After two iterations, beta beat was reduced from 4.6% to 0.5% horizontal and from 2.3% to 0.5% vertical in Jul. 2015.
   - With FOFB ON, RMS orbit motions in both horizontal and vertical planes met the specifications (below 10% of RMS beam size) in Aug 2015.
   - Bunch-by-bunch capability has been made available from NSLS-II BPMs (10 equally-spaced bunches can be resolved) in Sep 2015.

- Crosscheck of four different TbT-based algorithms for lattice correction. The measurement results show that the TbT-based algorithms (weighted correction of betatron phase and amplitude, independent component analysis, model-independent analysis, and driving-terms-based linear optics characterization) provide almost the same correction quality as LOCO, but they are much less time-consuming. Completed in Oct 2015.
- Program for linear lattice reproducibility accomplished an important step in Mar. 2016. Optimized magnet cycles found: quadrupoles and sextupoles - 4 cycles, 5A/s; dipoles - 20 cycles, 20A/s. High degree of reproducibility is achieved: for tunes - <0.001 and for beta-beat - <0.1%.
- Novel LOCO algorithm (AC LOCO) for linear lattice correction has been tested in comparison with the conventional DC LOCO, the results agree within measurement error bars in Jun 2016.

b. Beamline Developments Completed

Listed below are the important developments and milestones for each of the beamlines and their current status as of June 2017.

Port Location	**2-ID**
Beamline	SIX
Lead Beamline Scientist	Ignace Jarrige
Description	Soft Inelastic X-ray Scattering
Status	**Commissioning**
Portfolio	NEXT
Sponsor	DOE
Authorization to start commissioning FE/ID	18-Oct-2016
Authorization to start commissioning Beamline	17-Feb-2017
First Light	21-Feb-2017
General User Operations Date	Cycle 18-2

Port Location	**3-ID**
Beamline	HXN
Lead Beamline Scientist	Yong Chu
Description	Hard X-ray Nanoprobe
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	31-Oct-2014
Authorization to start commissioning beamline	31-Oct-2014
First Light	14-Nov-2014
General User Operations Date	9-Nov-2015

Port Location	**4-ID**
Beamline	ISR
Lead Beamline Scientist	Christie Nelson
Description	Integrated In-Situ & Resonant Hard X-ray Studies
Status	**Commissioning**
Portfolio	NEXT
Sponsor	DOE
Authorization to start commissioning FE/ID	30-Oct-2015
Authorization to start commissioning beamline	8-Jul-2016
First Light	11-Jul-2016
General User Operations Date	Cycle 17-2

Port Location	**4-BM**
Beamline	XFM
Lead Beamline Scientist	Ryan Tappero
Description	X-ray Fluorescence Microprobe
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-2

Port Location	**5-ID**
Beamline	SRX
Lead Beamline Scientist	Juergen Thieme
Description	Submicron Resolution X-ray Spectroscopy
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	31-Oct-2014
Authorization to start commissioning beamline	31-Oct-2014
First Light	8-Dec-2014
General User Operations Date	7-Dec-2015

Port Location	**6-BM**
Beamline	BMM
Lead Beamline Scientist	Dan Fischer
Description	Materials Measurement
Status	**Construction**
Portfolio	Partner
Sponsor	NIST
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-2

Port Location	**7-ID-1**
Beamline	SST-1
Lead Beamline Scientist	Dan Fischer
Description	Spectroscopy Soft & Tender-1
Status	**Construction**
Portfolio	Partner
Sponsor	NIST
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-3

Port Location	**7-ID-2**
Beamline	SST-2
Lead Beamline Scientist	Dan Fischer
Description	Spectroscopy Soft & Tender-2
Status	**Construction**
Portfolio	Partner
Sponsor	NIST
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-3

Port Location	**7-BM**
Beamline	QAS
Lead Beamline Scientist	Steve Ehrlich
Description	Quick X-ray Absorption & Scattering
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-2

Port Location	**8-ID**
Beamline	ISS
Lead Beamline Scientist	Klaus Attenkofer
Description	Inner Shell Spectroscopy
Status	**General User Operations**
Portfolio	NEXT
Sponsor	DOE
Authorization to start commissioning FE/ID	30-Oct-2015
Authorization to start commissioning beamline	3-Apr-2016
First Light	5-Apr-2016
General User Operations Date	23-Feb-2017

Port Location	**8-BM**
Beamline	TES
Lead Beamline Scientist	Paul Northrup
Description	Tender Energy X-ray Absorption Spectroscopy
Status	**Commissioning**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	13-Aug-2016
Authorization to start commissioning beamline	13-Aug-2016
First Light	17-Aug-2016
General User Operations Date	Cycle 17-2

Port Location	**10-ID**
Beamline	IXS
Lead Beamline Scientist	Yong Cai
Description	Inelastic X-ray Scattering
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	31-Oct-2014
Authorization to start commissioning beamline	31-Oct-2014
First Light	24-Nov-2014
General User Operations Date	12-Jul-2016

Port Location	**11-ID**
Beamline	CHX
Lead Beamline Scientist	Andre Fluerasu
Description	Coherent Hard X-ray Scattering
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	31-Oct-2014
Authorization to start commissioning beamline	31-Oct-2014
First Light	18-Nov-2014
General User Operations Date	14-Oct-2016

Port Location	**11-BM**
Beamline	CMS
Lead Beamline Scientist	Masa Fukuto
Description	Complex Materials Scattering
Status	**Commissioning**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	13-Aug-2016
Authorization to start commissioning beamline	13-Aug-2016
First Light	26-Aug-2016
General User Operations Date	Cycle 17-2

Port Location	**12-ID**
Beamline	SMI
Lead Beamline Scientist	Elaine Dimasi
Description	Soft Matter Interfaces
Status	**Commissioning**
Portfolio	NEXT
Sponsor	DOE
Authorization to start commissioning FE/ID	1-Mar-2016
Authorization to start commissioning beamline	7-Nov-2016
First Light	7-Nov-2016
General User Operations Date	Cycle 17-3

Port Location	**16-ID**
Beamline	LIX
Lead Beamline Scientist	Lin Yang
Description	Life Sciences X-ray Scattering
Status	**General User Operations**
Portfolio	ABBIX
Sponsor	NIH
Authorization to start commissioning FE/ID	7-Aug-2015
Authorization to start commissioning beamline	
First Light	16-Nov-2015
General User Operations Date	29-Oct-2016

Port Location	**17-ID-1**
Beamline	AMX
Lead Beamline Scientist	Dieter Schneider
Description	Highly Automated Macromolecular Crystallography
Status	**General User Operations**
Portfolio	ABBIX
Sponsor	NIH
Authorization to start commissioning FE/ID	7-Aug-2015
Authorization to start commissioning beamline	8-Mar-2016
First Light	8-Mar-2016
General User Operations Date	17-Feb-2017

Port Location	**17-ID-2**
Beamline	FMX
Lead Beamline Scientist	Martin Fuchs
Description	Frontier Microfocusing Macromolecular Crystallography
Status	**General User Operations**
Portfolio	ABBIX
Sponsor	NIH
Authorization to start commissioning FE/ID	7-Aug-2015
Authorization to start commissioning beamline	8-Jul-2016
First Light	8-Mar-2016
General User Operations Date	17-Feb-2017

Port Location	**17-BM**
Beamline	XFP
Lead Beamline Scientist	Jen Bohon
Description	X-ray Footprinting for In-vitro & In-vivo Structural Studies of Biological Macromolecules
Status	**General User Operations**
Portfolio	Partner
Sponsor	NSF/CWR
Authorization to start commissioning FE/ID	8-Jul-2016
Authorization to start commissioning beamline	8-Jul-2016
First Light	10-Jul-2016
General User Operations Date	24-May-2017

Port Location	**18-ID**
Beamline	FXI
Lead Beamline Scientist	Wah-Keat Lee
Description	Full Field X-ray Imaging
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-3

Port Location	**19-ID**
Beamline	NYX
Lead Beamline Scientist	Wayne Hendrickson
Description	Biological Microdiffraction Facility
Status	**Commissioning**
Portfolio	Partner
Sponsor	NYSBC
Authorization to start commissioning FE/ID	15-Nov-2016
Authorization to start commissioning beamline	22-Nov-2016
First Light	26-Nov-2016
General User Operations Date	Cycle 18-2

Port Location	**21-ID**
Beamline	ESM
Lead Beamline Scientist	Elio Vescovo
Description	Electron Spectro-Microscopy
Status	**Commissioning**
Portfolio	NEXT
Sponsor	DOE
Authorization to start commissioning FE/ID	7-Jul-2016
Authorization to start commissioning beamline	7-Jul-2016
First Light	25-Jul-2016
General User Operations Date	Cycle 17-2

Port Location	**22-BM-1**
Beamline	FIS
Lead Beamline Scientist	Larry Carr
Description	Frontier Electron Spectromicroscopy
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 19-1

Port Location	**22-BM-2**
Beamline	MET
Lead Beamline Scientist	Larry Carr
Description	Magnetospectroscopy, Ellipsometry, and Time-Resolved Optical Spectroscopies
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 19-1

Port Location	**23-ID-1**
Beamline	CSX-1
Lead Beamline Scientist	Stuart Wilkins
Description	Coherent Soft X-ray Scattering
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	16-Oct-2014
Authorization to start commissioning beamline	16-Oct-2014
First Light	23-Oct-2014
General User Operations Date	24-Jul-2015

Port Location	**23-ID-2**
Beamline	CSX-2
Lead Beamline Scientist	Ira Waluyo
Description	Soft X-ray Spectroscopy & Polarization
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	16-Oct-2014
Authorization to start commissioning beamline	16-Oct-2014
First Light	2-Feb-2015
General User Operations Date	10-Nov-2015

Port Location	**28-ID-1**
Beamline	PDF
Lead Beamline Scientist	Milinda Abeykoon
Description	Total Scattering Beamline
Status	**Construction**
Portfolio	BDN
Sponsor	DOE
Authorization to start commissioning FE/ID	
Authorization to start commissioning beamline	
First Light	
General User Operations Date	Cycle 18-3

Port Location	**28-ID-2**
Beamline	XPD-2
Lead Beamline Scientist	Eric Dooryhee
Description	X-ray Powder Diffraction
Status	**General User Operations**
Portfolio	LT
Sponsor	DOE
Authorization to start commissioning FE/ID	24-Oct-2014
Authorization to start commissioning beamline	24-Oct-2014
First Light	5-Nov-2014
General User Operations Date	7-Aug-2015

1.vi Ongoing R&D Activities at the Facility

Below we will provide a brief description of the ongoing research & development activities at the facility (accelerator improvements; beamline improvements; data processing; analysis and management developments; optic and detector developments, etc.).

a. Accelerator Development

The optimized NSLS-II storage ring lattice consists of 30 DBA cells, with straight sections alternating in length between 6.6 m and 9.3 m, with low and high values of horizontal beta functions, respectively. The performance goal of the 0.6 nm-rad horizontal emittance for the NSLS-II storage ring will be achieved when operating with a full complement of insertion devices, including damping wigglers and superconducting wigglers. The initial horizontal emittance of ~1 nm-rad is somewhat larger than this, due to the fact that only a limited number of insertion devices, including three 7 m damping wigglers, are present at the start of operations. The main design parameters of the NSLS-II storage ring and FY17 values achieved are summarized below.

Main Parameters of the NSLS-II Storage Ring	Design Value	Value in routine User Ops May 2017
Ring energy (GeV)	3.0	3.0
Ring current with top-off (mA)	500	300
Ring circumference (m)	792	792
Number of DBA cells	30	30
Number of 9.3 m straights	15	15
Number of 6.6 m straights	15	15
β_h in 9.3 m straights (m)	20.1	20.1
β_v in 9.3 m straights (m)	3.4	3.4
β_h in 6.6 m straights (m)	1.8	1.8
β_v in 6.6 m straights (m)	1.1	1.1
Vertical emittance (nm-rad)	0.008	0.025
Horizontal emittance (nm-rad)	0.6	0.9
RMS energy spread (%)	0.12	0.09
RMS pulse length (ps)	15-30	30
Interval between bunches (ns)	2	2
Revolution period (μs)	2.64	2.64
RF frequency (MHz)	500	500
Number of RF buckets	1320	1320
Number of bunches	1056	1056
Average bunch current (mA)	0.47	0.28
Average bunch charge (nC)	1.25	0.75

Table 1.vi.a.1: FY17 Main SR Design Parameters & Values Achieved

The NSLS-II accelerator systems were commissioned in 2014 and there has been steady progress towards achieving the design performance. We have increased the beam current every year, reaching 150 mA by the end of FY15, 250 mA by the end of FY16 and will be reaching or exceeding 300 mA by the end of FY17.

Reliability of operations is a constant focus. We have succeeded in steady improvement of reliability every year so far. As of May 2017, we have been operating with year to date reliability of 96.5% and are making major efforts in sustaining this level of performance.

Over the past two years the NSLS-II Accelerator Division has succeeded in:

- Increasing the circulating current in the storage ring to 300 mA in routine operations.
- Demonstrated a maximum circulating current of 400 mA.
- Installed, commissioned and integrated into routine operations 16 new insertion devices and three 3PW with their associated Front-Ends (FE), in addition to 6 original project IDs/FEs.
- Installed, commissioned and conditioned the second SC RF cavity.
- Commissioned the fast orbit feedback system and demonstrated required beam stability.
- Commissioned top-off mode of operations.
- Enabled a "sleeping mode" of injector operation for low power consumption and reduced orbit noise.

A detailed timeline of development of NSLS-II accelerators since completion of the beam commissioning was provided above. In the next three years, accelerator development activities will include the following areas:

Commissioning of new Insertion Devices, Front-Ends and Beamlines

Commissioning new undulators and wigglers together with their front-ends and support of new beam lines will be one of the main tasks of the NSLS-II accelerator activities. Start-up of a new beam line begins from commissioning its insertion device and proceeds along the following sequence: measurement of the device alignment and its impact on the ring lattice, correction of the residual fields as a function of the undulator gap, alignment of the x-ray beam with respect to the front-end and calibration of the slits, fault studies, and multi-stage radiation surveys at several ring current levels followed by subsequent vacuum conditioning of FE masks and the ID photon shutter. These commissioning activities are streamlined to reduce the impact to the facility operating schedule. Tools for fault studies, FE alignment, and feed-forward table measurements will continue to be developed and optimized.

Reliability of operations

Increasing reliability of operations is a high priority topic for accelerator improvement and development. In particular we concluded first year of operations, FY15, with reliability of 82% and evolved to 89.5% in FY16. This year we have been operating with reliability of 96.8% for the first 6 months and actively pursuing programs focused on reduction of faults and trips.

This progress satisfies our performance goals defined for FY16 as 3700 hours of operations with reliability about 90% and increased to 4500 hours and reliability level of above 95% in FY17.

Combined with the much reduced time scheduled for machine maintenance and shutdowns, this step in performance translated to a steep increase in the operating requirements as compared with FY 16. In order to meet these challenging goals, we have initiated and systematically followed several programs to increase the reliability of operations and to reduce downtime by improving every machine subsystem that was responsible for faults and subsequent beam dumps. Also we are investing into establishing routines of fast recovery from device faults to substantially reduce downtime during operations.

The number of beam dumps totaled 240 and 289 in FY15 and FY16, respectively, and we have accumulated 40 dumps for the first 7 months in FY17. Scaling the latter to the end of this FY we would get less than half of the faults seen in the prior year indicating substantial improvement of reliability of the machine subsystems.

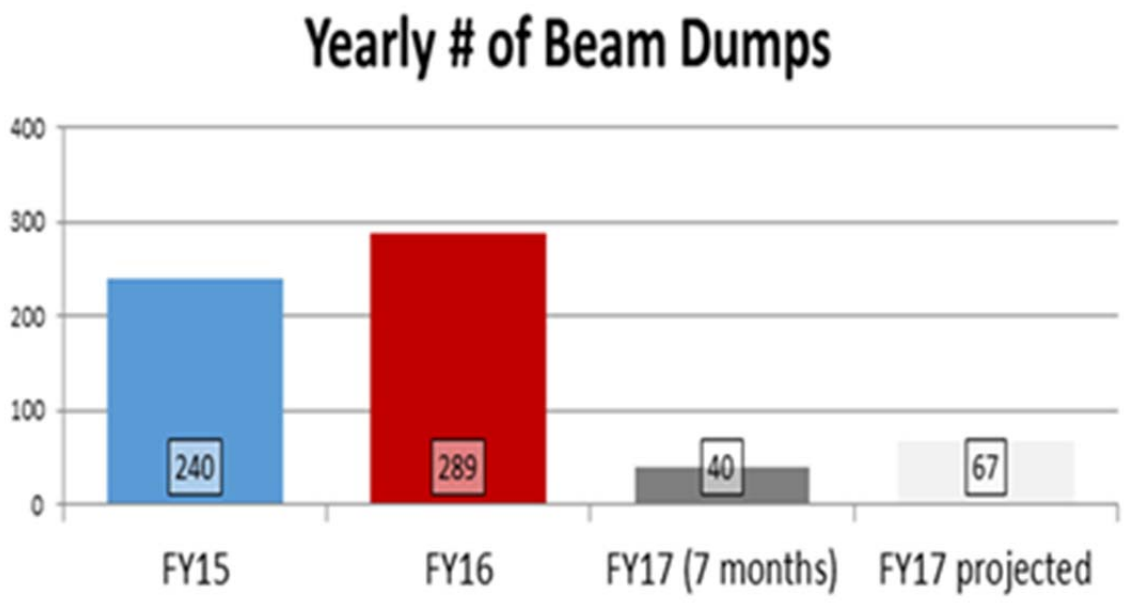

Figure 1.vi.a.1: Graph showing trend in the number of beam dumps in a given fiscal year. There have been 40 in FY17. If this rate is annualized, there would be 67 over the course of the fiscal year.

Total downtime is another major indicator of the machine performance. We have achieved a steady reduction of downtime every year since commissioning. Starting from 468 hours of downtime in FY15, we achieved 332 hours in FY16 and have an accumulated 54 hours in the first 7 months of FY17 operations, leading to 90 hours projected through the end of this year.

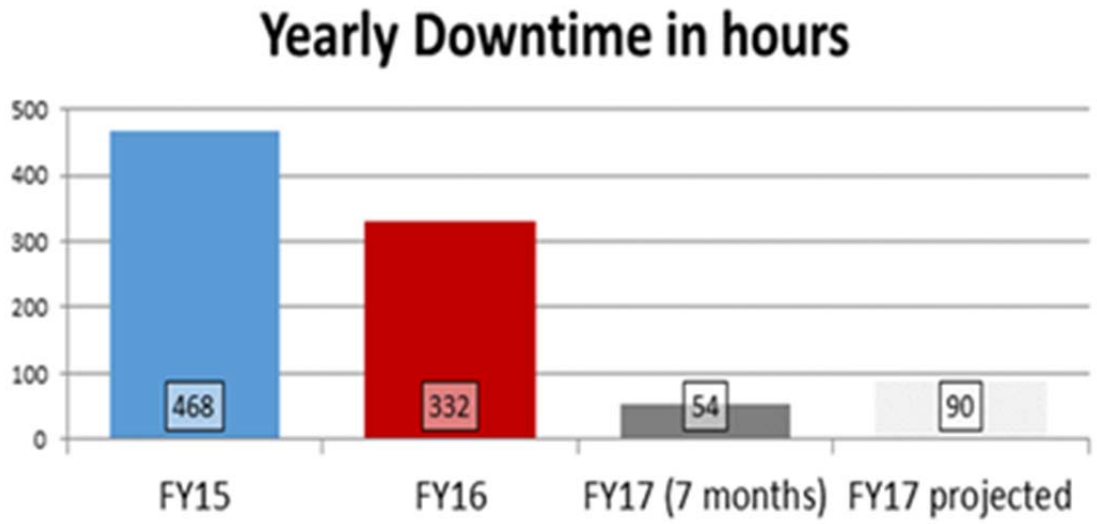

Figure 1.vi.a.2: Graph showing total downtime in hours by fiscal year. There have been 54 hours of downtime in FY17 at the time of writing. Projecting this rate through the full fiscal year would result in 90 hours of downtime.

In the following, we describe the various programs for improvement of operations reliability that have been established and followed.

In the past, one of the major sources of facility downtime was the malfunctioning of the accelerator enclosure door switches that are monitored by machine Personal Protection System (PPS). In FY 15 and 16 the Accelerator Division Mechanical and Electrical Engineering groups reworked all of the lock mechanisms thereby drastically reducing the number of PPS faults.

Commissioning and conditioning of the second RF cavity in FY 16 resulted in a substantial amount of downtime due to arcing and subsequent vacuum activity in the cavity and its waveguide. The RF group devised a process of partially warming the superconducting cavities followed by RF conditioning during maintenance days to increase the operating RF field in the second cavity. Today both cavities operate at the fixed voltage of 1.5 MV with each cavity delivering comparable power to the circulating beam.

Pulse modulators of the booster kickers have been experiencing frequent trips due to erratic operation of the pulsed power switches (cold cathode thyratrons). The Electrical Engineering group has designed and tested a modified kicker pulser employing an alternative switch resulting in more stable operation of the kicker systems. The first modulator of the new type has been installed in the booster for testing. Three more units are planned which will replace all cold-cathode thyratrons with conventional high-voltage switch tubes from E2V.

Commissioning and the first few years of operations have shown that the Thales klystrons used in the linac are performing below expectations in terms of stability, hindering top-off operation and beam availability. Frequent arcing and vacuum events in the tubes and waveguides have been bringing the linac klystrons down, and they require substantial effort to reset the interlocks and

restart the linac each time. The Accelerator Division RF group has prepared a plan to replace the linac klystrons with more stable Toshiba units. This program is currently under way.

A program to improve the reproducibility of machine performance has focused on achieving a high degree of control over machine parameters, such as orbit, tunes and beta-functions after beam dumps, maintenance periods and shutdowns. The magnet conditioning procedure has been optimized. Orbit and tune correction routines have been elaborated and improved. An NMR probe was installed in one of the large gap dipoles in the SR in order to provide an independent verification of the main dipole power supply performance. Today the orbit is reproduced within tens of μm after every restart.

SR Beam Position Monitors (BPM) were optimized for reaching stable operations. Additional constraints on the Active Orbit Interlock (AI) were implemented, reducing the frequency of the BPM-related trips to a marginal level. In particular, redundancy in processing the BPM signals was included in the AI algorithm to improve robustness of this system.

The beam recovery program was optimized to reduce the recovery time after each beam dump, initiated by tripping both RF transmitters. Beam recovery was optimized to reduce the time required to reestablish stored beam after an RF dump. Fast RF ramp-up together with fast beam fills were implemented, reducing the average recovery time after a beam dump from 45 minutes to 20 minutes.

In FY16 we initiated another program to increase operational reliability of the injector. The "100 MeV booster injection project" consists of modeling and an experimental study aimed at allowing booster injection at 100 MeV, thereby permitting the linac to operate with a single klystron. Since the booster synchrotron was designed for an injection energy of 200 MeV, requirements on the dipole field at 100 MeV will put very tight constraints on the power supply ramp profiles. The required power supply ramps will be established as the outcome of this program.

Increase in operating current

The NSLS-II operating current has continued to increase after commissioning. With the end goal of 500 mA we were gaining on average 100 mA per year while intensively studying performance of accelerator subsystems first at 350 mA and then at 400 mA.

During beam studies at 400 mA, the temperatures of the injection kicker ceramic chambers were found to increase rapidly with current, leading to potential overheating and damaging of the chambers. This effect was associated with heating of the chambers by the short intense wakefield from the electron bunches passing through the non-uniform titanium coating on the inner surface of the chambers. Several solutions to reduce the heating were devised and implemented. The short-term solution of installing fans blowing air directly on the kicker assemblies has been implemented and has cut the temperature increase in the chambers in half. A near-term solution is being pursued to manufacture spare chambers and develop higher quality metallic coatings in-house. A new ceramic chamber design with uniform coating is also being developed in collaboration with colleagues at other synchrotron radiation facilities. Long term, this problem

will be greatly mitigated by the third harmonic cavity which will stretch pulses by a factor of two or more in length.

Recently several bellows in the storage ring were instrumented with temperature sensors and temperature levels around 100 C were observed at 250 mA. While the mechanism of this overheating is under investigation we are planning on replacing the bellows of concern with the spare units.

Looking forward, the schedule budget for the beam studies which are performed primarily focused on ID/FE/beam line commissioning activities will have to be balanced with other accelerator activities needed for machine characterization and performance improvements to meet the needs of the scientific user community.

b. Beamline Improvements

Below we list planned and ongoing developments for the NSLS-II beamlines as grouped by beamline program.

Diffraction and In-Situ Scattering Program

In-Situ and Resonant X-ray Studies (ISR) Beamline. The *In-Situ* and Resonant X-ray Studies (ISR) beamline targets materials physics challenges in the areas of growth and processing, surface and interface structure, and magnetic and electronic structure. ISR supports an array of x-ray scattering techniques (*e.g.*, resonant x-ray scattering, crystal truncation rod measurements, x-ray reflectivity, grazing incidence small-angle x-ray scattering, and grazing incidence diffraction) in order to improve our understanding of novel materials.

Planned developments include (1) complete endstation fit-out, (2) complete commissioning of 6-circle diffractometer for hard x-ray scattering with full polarization control and analysis, and with displex cryostat. (6-300K), (3) complete commissioning of *in-situ* diffractometer endstation, (4) test primary focusing optics at several energies spanning the operating range of the beamline, (5) begin the task of implementing and developing streamlined software for diffractometer and beamline control, and data acquisition, (6) begin identifying and implementing appropriate software for visualization and online analysis of volume reciprocal space data that area detectors will enable, (7) investigate experimental methods that will allow one to operate detectors over the wide dynamic range required for surface/interface diffraction data: from bulk Bragg peaks (strong signal) to broad nano-sized growing surface domains (weak signal), (8) bring on-line the basic functionality of the Gas Handling System (GHS) for non-hazardous gases, (9) bring on-line the laser for PLD growth, (10) commission the KB focusing optics, (11) introduce hazardous and pyrophoric gases to the gas handling system for *in situ* growth study *e.g.*, GaN deposition, (12) integrate the mass flow controllers and switching valves of the gas handling system with the beamline controls, (13) implement timing synchronization between the pulsed laser and the x-ray area detector, (14) measure the coherent flux and properties of the beamline, and determine paths for improvement, and (15) implement kinoform focusing for the 6-circle diffractometer in Hutch C.

Pair Distribution Function (PDF) Beamline. Properties of most next generation materials are governed by imperfections in their atomic structures, such as, defects, nano- and multi-scale structures, heterogeneities, nanoscale disorder, stacking faults, surface relaxation, *etc*. It is important to understand the structure-property relationships in these materials to optimize their desirable properties. Diffraction patterns of such materials show broadened Bragg peaks and weak (or strong) diffuse scattering making them difficult candidates for traditional crystallographic approaches. Under this situation, the pair distribution function (PDF) method that utilizes both Bragg and diffuse scattering emerges as a powerful tool to study these materials. In the next year we plan to (1) complete construction of the PDF beamline, (2) initiate technical commissioning.

X-ray Powder Diffraction (XPD) Beamline. The X-ray Powder Diffraction (XPD) beamline serves a very broad and diverse user community ranging from physics, chemistry, and materials science to earth science, environmental science and engineering science. Planned and ongoing developments include: (1) mature instrumentation and automation of existing equipment, (2) develop hardware, controls and software for high resolution operations, (3) develop quasi real-time data processing, pipelining and visualization that build upon the XpdAcq/Bluesky software (in collaboration with Columbia University). This will provide in-line processing and automated analysis of data as they are flowing off the 2D detectors, in addition to search and database mining engines on processed data, (4) develop and commission an in-house 1D Ge strip detector, that consists of 384 0.5×0.125 mm^2 germanium elements mounted with a closed-cycle cryostat, and (5) develop additional sample environments in collaboration with users: a high temperature cell for a combined differential scanning calorimeter and diffraction, a microwave reactor for in-situ synthesis, (6) commission a photon-counting pixelated 2D detector with 130 μm pitch, (7) develop robot operations for high-throughput, combined with database mining, machine learning and Principal Component Analysis of the pre-processed data for guiding the user in real-time decision-making, (8) fit-out hutch D for stress-strain-time characterizations (in the 10 MPa, 10^{-5} range) of a multi-anvil system that consists of a 1,000 ton press using 25 mm^3 anvils with a uni-axial stress capability (applications are: rheology, elasticity, anelasticity and kinetics measurements) PU contribution, (9) develop micro-focusing optics in the D-hutch, using either kinoform-lenses and/or a set of in-vacuum Kirkpatrick-Baez mirrors, and (10) develop the fast diffraction tomography set-up (in collaboration with PU L. Ecker, BNL).

Imaging and Microscopy Program

Hard X-ray Nanoprobe (HXN, 3-ID) beamline. HXN is an undulator beamline in general user operations at sector 3-ID providing X-ray imaging capabilities with a world-leading spatial resolution. It offers a suite of X-ray analytical tools for structural, elemental and chemical imaging, with a resolution of 10 nm. The combination of unique detection capabilities and the unprecedented resolution enable noninvasive materials characterization at nanometer scale, critical for studies in many areas of science and technology. Planned and ongoing developments include: (1) optimize user operations for 2D X-ray fluorescence (XRF) imaging using the MLL microscope and the zone plate microscope, (2) enhance visualization and analysis of multi-modality imaging, which include elemental distribution (through fluorescence) and nanoscale morphology (through differential phase contrast (DPC) and ptychography), (3) enhance

robustness of 3D data collection through XRF tomography using the zone plate microscope, (4) optimize 3D XRF imaging capability using the MLL microscope, (5) provide a ptychography capability for general user experiments with a goal of achieving sub-5 nm resolution, (6) optimize in-situ experiments using electrochemical controls (for battery and corrosion research) and current/voltage measurements (for solar cells or other functional materials) where chemical (oxidation state) imaging will be carried out under in-situ controls, and (7) expand Bragg ptychography imaging capability for quantifying strain distribution within single crystal grains.

Sub-micron Resolution X-ray spectroscopy (SRX, 5-ID) beamline. SRX is an undulator beamline in general user operations at sector 5-ID that specializes in X-ray fluorescence microprobe and XANES spectroscopy with a spot size of ~0.7 microns and an energy range from 4.65 – 25 keV. Elemental imaging can be performed in 2D and 3D. A second endstation at SRX is currently under development that is expected to provide similar capabilities with sub-100 nm spatial resolution. Planned and ongoing developments include: (1) complete the implementation of sample fly-scanning to optimize routine XRF mapping, (2) resolve the heating issue with the monochromator motor so that XANES measurements are improved and EXAFS will be possible routinely, (3) continue to commission the Maia detector for routine user operations to enable fast XRF mapping of large sample areas, (4) commission the high-resolution KB optics to enable chemical imaging at sub-100 nm spatial resolution, (5) continue to work on complex sample environments such as in-situ/operando cells for research on functional materials or a cryostage for radiation-sensitive soft materials, (6) commission XRF-tomography to enable elemental mapping in 3D with sub-micron resolution.

Full-field X-ray Imaging (FXI, 18-ID) beamline. FXI is a damping wiggler beamline currently under construction at sector 18-ID that will house a Transmission X-ray Microscope (TXM) with 30 nm spatial resolution and 20-40 micron field of view. At 500 mA NSLS-II operation, the expected exposure time per image is < 100 ms. FXI will also be capable of nanoXANES, which will allow for elemental imaging and speciation. The scientific scope of the beamline will focus on 3D in-situ and operando dynamics of sample morphology and oxidation states imaged at 30 nm spatial resolution. Planned and ongoing developments include: (1) finish construction of the beamline, with the Instrument Readiness Review (IRR), (2) getting the TXM instrument operational – in particular, the data acquisition, management and analysis (DAMA) aspects, (3) achieve 30 nm spatial resolution with projection image exposure times below 1s, (4) begin science commissioning with expert users, (5) establish external collaborations for in-situ sample environment cells and x-ray optics, and (6) participate in multi-modal science with other NSLS-II/BNL collaborators.

X-ray Fluorescence Microprobe (XFM, 4-BM) beamline. XFM is a 3-pole wiggler beamline under construction at beamline 4-BM that will provide unique spectroscopic microscopy capabilities because it will span the tender (2-5 keV) and hard (5-23keV) energy range (P to Tc K-edges), and also offers a polychromatic "pink" mode ideal for rapid 2D and 3D fluorescence imaging and tomography. It will employ compound focusing to achieve a tunable spot size from 1 to 10 microns while maintaining a long working distance for physically large samples and custom in situ environmental cells. . Planned and ongoing developments include: (1) finish construction of the beamline, with the Instrument Readiness Review (IRR), (2) beamline characterization and technical commissioning activities, (3) enabling on-the-fly 2-D X-ray fluorescence imaging (i.e., XRF mapping) and microbeam X-ray absorption near-edge structure spectroscopy.

Complex Scattering Program

Inelastic X-ray Scattering (IXS, 10-ID) beamline. The inelastic X-ray scattering (IXS) beamline is dedicated to ultrahigh resolution studies of phonon dynamics in an energy and momentum space important for understanding the properties of industrially relevant materials systems that exhibit complexities and inhomogenieties at mesoscopic length scales. IXS plans to: (1) develop/procure a single-reflection paraboloidal multilayer mirror to replace the Montel mirror of the analyser optics to improve the reflectivity by nearly a factor of 2; (2) identify and establish a collaboration with an external vendor to improve the quality of the high-resolution crystal optics with the goal to improve the energy resolution of the IXS spectrometer to below 1 meV; (3) improve the thermal stability of the high-resolution crystal optics to limit energy drift to less than 0.1 meV over 12 hours to facilitate long data collection time; (4) complete the development of sample environments for humidity and temperature control for bio samples, and the integration of a membrane DAC with the existing cryostat; and (5) implement and develop streamlined software for experimental control, data acquisition and online analysis within the NSLS-II standard BlueSky framework.

Coherent Hard X-ray Scattering (CHX, 11-ID) beamline. The Coherent Hard X-ray (CHX) beamline offers its user community a best-in-class instrument for coherent scattering and X-ray Photon Correlation Spectroscopy (XPCS) in the 6-16 keV range with beam sizes between 2-10 μm. CHX plans to: (1) complete endstation construction work, with a particular focus on the control systems for the SAXS and WAXS instruments; (2) fabricate and test kinoform focusing optics for two spot sizes (2 μm and 10 μm) and several energies spanning the operating range, (3) extend user operations to coherent scattering in WAXS or SAXS/WAXS geometries, and (4) achieve routine user operations with all planned beamline capabilities including the complete range of working energies (6-16 keV), beam focused to ~2 um for WAXS, ~10 um for SAXS, and with a range of different sample environments.

Complex Material Scattering (CMS, 11-BM) beamline. The CMS program aims to facilitate the discovery, design, and optimization of functional materials by developing capabilities for (i) *in situ* structural characterization under processing conditions and (ii) intelligent exploration of large parameter spaces. CMS plans to: (1) install the new SAXS detector (a vacuum-compatible Dectris Pilatus3 2M), modifying the existing SAXS detector stage and flight path exit window to accommodate the new detector; (2) begin development and procurement of *in situ* sample cells, with initial emphasis on heat and tensile stages and a solvent annealing cell; (3) install a prototype sample exchanger; (4) commence the approved Partner User program with the CFN and finalize a strategy to automate beamline workflow through hardware and software enhancements; (5) install, test, and integrate an initial set of in-situ sample cells for general users; (6) commission high-throughput operation based on the prototype sample exchanger; and (7) with the CFN, design, fabricate, procure and install hardware enhancements for automation.

Soft Matter Interfaces (SMI, 12-ID) beamline. SMI is one of a very few beamlines worldwide that provide SAXS/WAXS in the tender X-ray range. SMI plans to: (1) complete technical commissioning of the photon delivery, sample positioning, and data acquisition/management systems; (2) complete science commissioning of the time resolved GI-SAXS capability: (3) complete technical and science commissioning of the wide/medium angle (WAXS/MAXS)

detectors (the MAXS detector is provided by the CFN Partner); (4) start General User (GU) operations and continue technical commissioning of additional capabilities, including time-resolved GISAXS; (5) add WAXS/MAXS to the GU offering; (6) characterize the micro-focused beam over the full energy range and offer as soon as possible to GUs; (7) develop tender X-ray capability; and (8) complete design and begin installation of a liquid spectrometer by adapting existing instrumentation from the former 9-ID liquid spectrometer at the APS, recently transferred and shipped to BNL.

Hard X-ray Spectroscopy Program

Inner-Shell Spectroscopy (ISS, 8-ID) beamline. ISS is a high-flux hard X-ray spectroscopy beamline based on a damping-wiggler source and is optimized for *operando* and *in-situ* experiments. We plan to commission all hardware and software for the beamline which includes (1) the automated sample changer of the sample chamber, (2) Gas Handling System (GHS), and (3) two von Hamos spectrometers. In addition (4) fast scanning three-element backscattering analyzer system synchronized with the monochromator, will be developed and commissioned, (5) an initial set of sample environments, compatible with the automated sample changer for battery research, electro-chemical cells, and chemical gas-flow- reactors will be constructed and commissioned, and (6) we will develop a high-pressure reactor sample cell for heterogeneous catalysis, and focus the in-house program on nanoporous catalytic systems with a focus on selectivity.

Quick X-ray Absorption and Scattering (QAS, 7-BM) beamline is a high-throughput hard X-ray beamline based on a 3-pole wiggler source. We plan to (1) complete construction and begin technical commissioning with emphasis on the upgraded monochromator system, including control, (2) enable battery and electrocatalysis experiments.

Tender Energy Spectroscopy (TES, 8-BM) beamline is a unique X-ray beamline optimized for spatially resolved X-ray absorption spectroscopy and fluorescence imaging in the tender energy range of 1-8 keV, using a bending magnet source. Compound focusing provides a user-tunable spot size from ~1 to ~100 um; the sample environment is non-vacuum (helium). Ongoing and planned activities include technical and scientific commissioning in a phased approach, providing Users with XRF imaging and microbeam XAS, and implementing in-situ or operando capabilities.

Spectroscopy Soft and Tender (SST-1 and SST-2, 7-ID) is a canted insertion device beamline which provides a soft energy branch (SST-1) with an energy range from 100eV to 2.2keV and a tender energy branch (SST-2) with an energy range from 1keV to 7.5keV. In the next year, we plan to (1) complete installation and (2) prepare commissioning plan along with IRR.

Materials Measurement (BMM, 6-BM) is a high flux 3-pole wiggler beamline optimized for hard X- ray spectroscopy and diffraction. The planned and ongoing activities include (1) completion of construction and installation, (2) perform technical commissioning and enable XAFS for the GU program, (3) develop diffraction capabilities.

Soft X-ray Spectroscopy and Scattering Program

Soft Inelastic X-ray Scattering (SIX, 2-ID) beamline is an undulator beamline designed and constructed to study the collective excitations in materials such as correlated oxides. SIX plans to (1) complete technical and science commissioning of the photon delivery system/m; (2) complete technical and science commissioning of the variable *q* endstation; (3) investigate possibilities for analyzing the polarization of the scattered radiation and (4) develop, in collaboration with CMPMSD and the DAMA group the online analysis of RIXS spectra (including theoretical modeling of correlated electron systems).

Coherent Soft X-ray Scattering (CSX-1, 23-ID-1) beamline is an undulator beamline designed and constructed to provide the highest coherent flux for x-ray scattering experiments. It is particularly suited to experiments to study at the temporal and spatial properties of electronic textures in quantum materials. CSX-1 plans to (1) run the general user (GU) program providing XPCS measurements; (2) Develop soft x-ray nano-diffraction techniques in collaboration with MIT. (3) Develop coherent diffraction imaging to study electronic textures in a single shot. Finally (4) investigate the possibility of using a zone plate energy filter for high sensitivity diffraction experiments.

Soft X-ray Spectroscopy and Polarization (CSX-2, 23-ID-2) beamline is an undulator beamline designed and constructed to provide high flux and high resolution for soft x-ray spectroscopy measurements. The science program of this beamline centers around the study of catalysts and energy related materials. The CSX-2 beamline plans to (1) Run the GU program of the ambient pressure XPS endstation in collaboration with the CFN; (2) Continue to develop the in-operando XAS endstation – including novel sample cells for liquids – in collaboration with BNLs' Chemistry Department; (3) develop, in collaboration with both the CFN and the DAMA group the automation of the gas handling system and sample transfer mechanisms.

Electron Spectro-Microscopy (ESM, 21-ID) beamline is an undulator beamline designed for high flux, high resolution electron spectroscopies with a focus on providing the best spatial resolution with both ARPES and X-PEEM endstation capabilities. ESM plans to (1) Start science commissioning on the ARPES branch leading to GU operations; (2) Start science commissioning on the X-PEEM branch in collaboration with the CFN; (3) Develop micro ARPES scanning for spatially resolved ARPES; (4) Install, commission and run the MBE growth capability in collaboration with Yale University; (5) Continue to develop the "*sample highway*" as a complete UHV sample system for integrated measurements of quantum materials.

Frontier, Magnetic, Ellipsometric and Time-Resolved Infrared Spectroscopy (FIS & MET) beamlines are fed from a large gap dipole IR source to provide the largest possible spectral range needed for condensed matter and geophysical infrared spectroscopy with unique sample environments. The FIS/MET beamlines plan to (1) Finish construction of the FIS/MET beamlines and associated endstations; (2) Successfully complete the instrument readiness review for these beamlines and (3) start technical and science commissioning of the endstations transferring capabilities into the general user program as available.

Structural Biology Program

Highly automated macromolecular crystallography beamline (AMX, 17-ID-1) is a highly automated macromolecular crystallography beamline with best in class flux among the mini-beam lines. Its capabilities overlap and complement those of the FMX micro-diffraction macromolecular crystallography with which it shares sector 17-ID. AMX plans to: (1) establish state-of-the-art automation that supports extremely high-throughput data collection capabilities, including full dewar operation, sample robot trajectory optimization, and sample auto-centering, with the (2) IT and Controls capabilities to provide data collection queuing, a scalable high-volume sample database back- and front-end including high-volume storage and data-transfer to the users, establish and develop (3) high-performance computing facilities and optimized applications to support data-screening, data-collection and data-processing at full detector speeds of the Eiger detectors, (4) develop an automated structure solution pipeline, (5) provide remote access to the experiment and (6) establish infrastructure to support high-throughput "dynamics" studies involving room temperature data collection.

Frontier macromolecular crystallography beamline (FMX, 17-ID-2) is an undulator beamline at sector 17-ID for structural biology investigations with micro-focusing macromolecular crystallography (MX), optimized for challenging bio-crystallographic problems. Its flux density is unmatched by MX facilities world-wide. FMX plans to: (1) establish the smallest beam focus of one micron for routine data collection, (2) develop the requisite controls automation to enable raster scanning and serial data collection on small (very small) crystals (3) establish sample mounting performance with the complete 384 specimen storage dewar to minimize hutch access and associated temperature instabilities, (4) improve beam stability through diagnostics and accompanying active beam position feedback from the electron beam orbit to the experimental station as well as through minimization of environmental noise and drifts (5) automate beam alignment routines for undulator, mirrors and monochromator and (6) through in-house and collaboration partners test and develop new sample delivery methods, such as micro-manufactured Si-chip sample holders and viscous crystal jets.

Life Science X-ray Scattering (LIX, 16-ID) beamline is an undulator beamlined designed and constructed to study structure of macromolecules in solution; scattering-based imaging of biological tissues and membrane structures. LIX plan to (1) complete the temperature-controlled sample environment for high-throughput solution scattering experiments; (2) install the 6-axis robot inside the experimental station and develop software to perform unattended solution scattering measurements; (3) develop automated processing and analysis pipeline for solution scattering data; (4) with help from the DAMA group, optimize the data processing code for scattering-based scanning imaging measurements.

c. DAMA

In this section we discuss the development for data acquisition, data analysis, and data management.

The NSLS-II beamline data acquisition, data management and data analysis systems are built to provide the essential data and computing infrastructure, one that can grow and evolve over the life

of the facility. NSLS-II has developed a powerful and flexible suite of open source software packages that can not only support new detectors and new techniques as they continue to evolve, but also allow for an analysis of the quality of the data as it is being collected and of the performance of the beamline. The user facing data acquisition package is called Bluesky and is utilized for control of the experiment and the collection of scientific data and metadata. Bluesky interacts with the beamline hardware through the standard programming language, Python, using the EPICS interfacing software. Bluesky v0.9 is currently running on the operational beamlines of NSLS-II.

In order to educate and elicit feedback from the user community, we held a tutorial workshop on Bluesky at the 2017 NSLS-II Users Meeting. This provided a good forum to gather feedback from users both on what they like and what their requirements will be in the future. We plan to continue holding such workshops on a regular basis in the future.

At the time of writing, we are refining the requirements and feature set for the first formal release of Bluesky v1.0, which will occur by the end of FY17. The baseline features have been defined to fulfil the day-to-day requirements of the currently operating beamlines. Some of the high level functionality includes (but is not limited to): complex step scans including N-dimensional, complex spiral trajectories, etc., fly scans, reciprocal space scans, adaptive scans (i.e. feed measurements back into the plan), sophisticated streaming analysis (e.g. live tomographic reconstruction), manual and automatic suspend/resume (e.g. in response to beam dump), simulation mode, and the requirement that all known hardware on operational beamlines be supported. After the first release, successive versions of Bluesky will focus on providing a more streamlined user experience with more graphical user interfaces (GUI) for composing and executing scans/plans, together with beamline specific GUIs that will be tailored for specific techniques. It is planned to develop the generic interfaces that can be used on all beamlines first, then move onto specific techniques. The priority in development of specific GUIs will be driven both by the expectations of the user community for the given technique and the development effort required.

At the core of the NSLS-II data acquisition and data management system is a set of flexibly structured data stores. These store all data and metadata related to an experiment. The "Data Broker" application interface retrieves and manages data and metadata from a distributed set of data stores. This set of data stores are tailored for specific types of experiments, and store not only the raw data from a detector, but also additional metadata from the beamline, accelerator, logbooks, proposal, sample management and scheduling systems. The data broker is a key piece of data handling interface software. It enables the development of data analysis procedures for visualization and analysis of the real-time data to allow decision making, and for post-processing of all data after the actual experiment.

The Application Programming Interface (API) to the Data Broker is well defined and major changes to this are not anticipated. Going forward, effort will be focused on developing the architecture and services to allow remote access, a more flexible method of accessing data and in storing data in the format that is optimum for the given use case (e.g. using a HDF5 backed event store for very high data rates instead of a MongoDB database). These objectives will be accomplished by the end of FY18.

In order to make sure that we have the ability to keep up with users' expectations on performance, we plan to perform a number of performance tests and investigations into different options for data streaming and processing. The initial performance tests will be conducted within FY17, which will provide a baseline for the bandwidth between CSI and NSLS-II. This test will consist of transferring both synthetic and real experimental data between the beamline computers and the CSI. These tests will be performed by staff from the SDCC and NSLS-II IT.

In order to capture the data processing workflow, and provenance, we intend to investigate potential solutions in collaboration with CSI. By doing this we can not only provide the scientists with a 'log' of everything that was done to their data to get to the final result but also enable reproducible and open science.

To be able to accommodate the high data rates and high data volumes at beamlines, NSLS-II is implementing a multi-tier data management system to ensure efficient and adequate storage for complex experimental data from beamlines. Initially, this multi-tier system will consist of one or two tiers (depending on the beamline requirements), namely local to the beamline and central NSLS-II storage. This will be then extended by adding connections to CSI for long-term storage and near-compute level storage. The current estimates show that the NSLS-II will produce between 10-20PB per year in 2018-2019. A detailed data center plan will be produced during the first half of FY18. It will include an investigation in the use of cloud based resources (e.g. Amazon, Google, etc.) to be performed in order to evaluate the potential benefits and drawbacks for this approach. We are currently evaluating a digital archive system for NSLS-II data, based upon the Invenio/Zenodo software platform in collaboration with CSI.

It is our intention to fully engage with community efforts concerning data management and storage. To this end, we have made good initial progress in defining an initial set of sixteen metadata items that will be stored along with published datasets from the NSLS-II, APS, SNS and HFIR beamlines. The development of a standard methodology and schema for collection of metadata items is in the planning stage and is expected to deliver a prototype for a set of pilot experiments by the end of FY18. We have experts in data and metadata definitions within the NSLS-II but will also leverage expertise from CSI and the Photon and Neutron Special Interest Group (PaNSig) of the Research Data Alliance. By engaging with other facilities on data standards we can enable multi-modal type experiments across facilities.

As part of our plan in data science, it is crucial that we update our data management policy so that our users have a clear understanding and expectation on what NSLS-II and BNL will provide in terms of data storage, retention and access. The first step in developing a policy will be to benchmark what the other BES-SUF's data policies are. The cost will also be a major factor in the final data management policy. A draft version will be produced during FY18 for review and comment.

Based on the data architecture and the data broker interface, a library of software routines and tools is being developed within the multi-tier data management system. These tools are being tailored to meet the needs of specific types of techniques, experiments, and scientific disciplines. The software and tools developed are released under the 'scikit-beam' umbrella project, which has users and contributors from multiple facilities.

It is important to state that our approach will be to reuse and collaborate on the development of existing software that meets our requirements. Developing entirely new code will be avoided wherever possible. This approach is facilitated with regular "hackathons" in which the code developers from across the DOE scientific user facilities collect together, share code and experience and work together to solve common issues. In addition, NSLS-II is developing a joint R&D plan with the APS in regard to software development. The plan will cover areas in which the two facilities can work together on specific projects and areas in which the two can standardize on selected third party projects (e.g. Xi-Cam from the CAMERA project). It will also encompass the data management requirements and policies for both facilities and highlight opportunities for closer collaboration.

Anticipating the greater need for post-experiment data mining and processing, NSLS-II will work with other stakeholders on computing within BNL to develop and operate a central data processing computing facility as part of the multi-tier data management system. The main goal of this facility is to provide front-end computing and centralized data storage/archiving system for NSLS-II users. This will allow them to access their data on-site during the experiment and also later when they return to their home institutions.

d. Optics Development

In this section we discuss the planned and ongoing developments for NSLS-II Optics R&D Activities at NSLS-II.

Meeting NSLS-II strategic objectives to establish and retain NSLS-II leadership in high-spatial-resolution imaging and in high-coherent-flux scattering requires the development and characterization of a number of advanced X-ray optics and the development of state of the art Nano motion end stations.

Leveraging the experience gained and the infrastructure established during the NSLS-II construction phase, we are pursuing advanced optics and nano positioning R&D using the following strategy:

(1) Establish the next-generation of nanofocussing optics (MLLs, Refractive lenses and mirrors) to support NSLS-II strategic objectives.
(2) Expand the optical nanometrology and At Wavelength Metrology/alignment R&D to support NSLS-II beamline operation.
(3) Support all this above capabilities with advanced methods of optics modeling.
(4) Expand the mechanical nanometrology to all imaging experiments requiring sub 50 nm resolution

The essential and integral part of the NSLS-II Optics R&D program is to develop novel X-ray optics and the associated tools to characterize, simulate and utilize them. The NSLS-II Optics R&D program follow the 2013 DOE X-ray Optics workshop report*, (X-ray Optics for BES Light Source Facilities) as a roadmap. This section describes these four R&D areas that are critical to enable the NSLS-II beamlines to achieve their best-in-class performance and capabilities.

Establish the next-generation of nanofocusing optics (MLLs, Refractive lenses and mirrors) to support NSLS-II strategic objectives.

NSLSII is pursuing two main R&D thrusts in this area:

Leveraging several critical advances in Multilayer Laue lens (MLL) optics development made the past few years, we plan to continue to lead the development of MLL optics by advancing the necessary thin-film deposition including materials selection, sectioning and polishing techniques, and characterization as well as developing related metrology techniques to fabricate and implement tilted and wedged MLLs and their associated mechanical systems to achieve 5 nm focus in the 10-20 keV range.

Specifically, we have 2 main goals: First, the development of wedged MLL with minimal residual error (<5nm) in order to break the 10nm mark, enabled through continuous developments in deposition, sectioning and metrology. The targeted energy is 15 keV with a focal length of about 2.5 mm. Second, the growth of large aperture MLLs for the development of bonded/monolithic MLL pairs (nanofocusing optics). These developments will, for example, enable easier incorporation of MLLs onto X-ray microscopes at NSLS-II (and elsewhere) thanks to a significantly reduced requirement on the number of degrees of freedom for alignment and the higher mechanical stability. It will also enable the use of MLL optics for full-field microscopy. In order to grow very thick films, different material systems other than the WSi/Si combination used for high resolution high efficiency MLLs will be considered in order to reduce the stress accumulation in the film which makes it prone to defect formation during the growth and sectioning (such as cracks, breakage...). New materials investigations will be done in collaboration with APS.

Through an SBIR partnership, an evaluation of the performances of Atomic Absorption Spectroscopy for in-situ deposition monitoring and in-situ metrology is being conducted. After optimization, the tool will be integrated permanently onto the deposition chamber. This will give us the ability to estimate the quality potential of a MLL growth before one moves to more accurate, but time consuming, metrology.

In parallel, some R&D has been started on ion-beam figuring to couple deterministic polishing and high accuracy optical metrology under an LDRD-funded program. These capabilities will offer the option to build some highly curved focusing mirrors in-house.

R&D on Kinoform lenses, a type of refractive lens, is ongoing at NSLS-II and has led to some Si kinoform lenses being installed at the CHX beamline. These lenses are the primary beamline focusing optics for the CHX beamline, and have been in place for all CHX users for the last two cycles. The kinoform optic is a good match for beamlines that try to preserve the excellent phase profile of the NSLS-II source. However, the CHX beamline needs additional lenses to increase the flux in the focused spot, and lenses for a wider range of energies to meet the user requests. In order to make these improvements, we will need to:

- Make improvements in the lens fabrication processes that are currently hosted at BNL's Center for Functional Nanomaterials. Specifically we will increase the lens apertures and reduce aberrations by optimizing fabrication steps.

- Characterize the subsequent lenses with x-rays; and
- Feedback the information from characterization into improved lens design and fabrication.

A recent accomplishment has been obtaining a spot size of 660 nm at photon energy of 102 keV on beamline 1-ID at APS. This work, and similar prior results, have enabled us to obtain funding from DOE, specifically for M&S to purchase the equipment needed to make measurements on the tens of nanometer scale. While this award is to improve kinoform lenses for high energy (E > 50 keV photons), the equipment developed will also be useful for the lower photon energy lenses that will be of interest to many of the NSLS-II beamlines, including CHX, XPD, ISR, SMI and HEX.

In collaboration with the Nano-positioning Group we are creating a portable endstation which will resolve x-ray spot sizes of 100 nm and less and will have positional accuracy on the order of 10 nm. This end-station will be crucial for characterization of lenses with the detail necessary to allow improvements of design and fabrication noted above.

We will continue R&D efforts in refractive and kinoform lenses using silicon and diamond at NSLS-II. The bulk of our effort will be dedicated to improving etch depth and uniformity. In FY16 we improved lens etch depth from 100 microns to 125 microns, a 25% improvement. Some test structures were etched down to 300 microns. For FY 17 we intend to transfer the depths obtained on test structures to actual lenses, aiming for a more conservative etch depth of 150 microns, and in FY18 aim for an etch depth of 250 microns. Starting in FY19 we anticipate fabricating lenses with apertures of 300 microns or greater, by building on the improved fabrication processes evaluated in FY17 and FY18. We also anticipate lens resolutions that would be sub-100 nm, for photon energies at 50 keV and above. Lenses fabricated with these methods, but customized to the wider range of photon energies and focal lengths that users request, will deployed to NSLS-II beamlines and APS beamlines. We would also improve our lens characterization end-station to have step sizes of 3nm instead of 10nm, in anticipation of characterizing lenses with a sub-30 nm spot size. This end station could be used for characterization of Zone Plates, MLLs and small KB pairs.

Optical Metrology / At Wavelength Metrology / Wavefront preserving mirrors development

Many of the high-impact scientific opportunities at the nanoscale afforded by NSLS-II, such as coherent X-ray imaging, nano-diffraction, and nano-spectroscopy, require maximum intensity in the focus and minimal wavefront distortion. These applications require X-ray mirrors with ≤0.5 nm rms height errors and sub-100 nrad slope errors for surface spatial frequencies ranging from 100 microns to the full optical aperture of the optic. These characteristics are extremely close to the present noise floor for short flat mirrors and are sometimes beyond the state-of-the art for highly curved mirrors. Leveraging the unique expertise and the cutting-edge optical metrology capabilities acquired through the NSLS-II construction project, our strategy is to identify and pursue a number of targeted initiatives where NSLS-II will continue to play a significant leadership role in the development and metrology of advanced X-ray mirrors for coherent applications. These initiatives include:

Continued development of next generation metrology tools and techniques

This is essential to enable measurements of figure errors at sub 100-nrad levels. This will be done by upgrading instrumentation in the existing NSLS-II optical metrology laboratory, in parallel with efforts on the development of new instruments for slope errors measurements to reach 50 nrad slope error accuracy) and stitching interferometry capabilities for sub nm rms accuracy for highly curved mirrors. These combined efforts towards the construction of new instruments with stitching capabilities using an interferometer, a Shack Hartmann and software configurable optical test (SCOTS) stations will be able to perform 2D mapping of the optical surfaces in order to feed a deterministic polishing process based on ion beam figuring. This activity will consist of:

1. Identify, and develop new metrology instruments with the goal to improve the ultimate accuracy towards 50 nrad rms for slope and nm rms for height.
2. Implement and develop dedicated stitching software, data acquisition and online analysis.
3. Reduce the measuring time for mirror metrology while keeping the ultimate accuracy

Wavefront preserving mirror R&D

X-ray mirrors are used extensively at NSLS-II, but there are only a small number of industrial companies who can supply such mirrors. This small number of possible suppliers is a significant risk. In addition, the products are very expensive and production times can be very lengthy. We propose to set up equipment at NSLS-II for deterministic polishing or preferential deposition R&D, similar to those at facilities such as APS, ESRF, MAXIV, BESSY and DIAMOND. Such a facility would let us achieve in house diffraction limited focusing of X-rays mirror development. Some key milestones for FY17-18 are:

1. Design a state of the art Ion Beam Figuring platform with the goal to produce high quality curved x-ray mirrors.
2. Test software, data acquisition and online analysis.
3. Implement and develop a state of the art Ion Beam Figuring platform
4. Achieve first test of a dedicated KB system.

This R&D is funded through an LDRD Project.

Development of At Wavelength and In Situ metrology tools and techniques

Availability of adequate measurement tools and adjustments directly at the beamlines is crucial for a thorough ***optimization*** of operational performance of individual beamline components and of entire beamline systems. This R&D capability coupled with extensive simulation development is supported through a BES grant and will follow until end of FY18.

The key developments foreseen are:

1. Development of necessary functions in the software package, “Synchrotron Radiation Workshop” to simulate a wavefront analyzer based on the Hartmann approach, and other possible sensors and geometries.
2. Develop procedures for in situ beamline alignment and adaptive optics in closed loop
3. Procure the key components for the wavefront sensor: camera, lenses, mechanical system, scintillators, gratings, grids, etc.

4. Test of the wavefront sensor at wavelength in the SRX and HXN beamlines. Preparation of the closed loop feedback between the wavefront sensor and adaptive optics system.

Advanced methods of optics modeling

Over the recent years, we have:

- Continued the development and support of "Synchrotron Radiation Workshop" (SRW) code for high-accuracy calculation of synchrotron emission and simulation of fully- and partially-coherent wavefront propagation through X-ray optical components.
- Developed an efficient method for spectrum-based alignment of In-Vacuum Undulators (IVU) and applied it at a number of NSLS-II beamlines (SRX, CHX, SMI, LiX) in collaboration with the beamline teams; this resulted in improvements of the beamline spectral performances.
- Contributed to the commissioning of transport optics at some NSLS-II beamlines (CHX, SRX, HXN, and others) by analyzing and benchmarking measured X-ray intensity distributions against simulations.
- Assisted in development / formulation of new beamline projects / proposals (HEX, ARI, CDI, INF) by simulations related to X-ray sources and optics.

The key important immediate milestone is setting up "virtual beamline" environments in SRW code under newly-developed "Sirepo" web- / cloud-computing interface for **ALL** existing and planned NSLS-II beamlines. The priority in FY17-18 will be given to the operating beamlines that strongly rely on coherence, high brightness and high flux of synchrotron radiation (i.e. CHX, CSX, HXN, SRX and IXS), and to beamlines that are undergoing commissioning in FY17 (SMI, ISR, ESM, SIX, FMX, AMX, and LiX). Then, in parallel with this, "virtual beamlines" will be set up for the new proposed beamline projects including CDI, ARI, INF, PLS, SMF and QIX – to facilitate further optimization of their sources and optical layouts.

In parallel, the library of optical element "propagators" will be further extended to include such optical elements as (in the order of priority) Multilayer Laue lenses, imperfect compound refractive lenses, zone plates with very large numbers of zones and their typical imperfections, kinoform lenses, mirrors of all practically-important shapes and imperfect crystals in different geometries, incorporating height profile error data from Optical Metrology and heat load-related deformations predicted from Engineering FEA simulations.

There is also a need for continued improvement of numerical efficiency and reliability of the partially-coherent wavefront propagation simulation methods. This includes further optimization and parallelization of existing algorithms, testing new algorithms and improvement of an automatic propagation "driver".

Performing "assessment" of real performances of NSLS-II beamlines will speed up beamline commissioning and problem solving. This will ensure that in a reasonably short time ALL beamlines will maximally exploit the low emittance / high brightness of the NSLS-II, and deliver higher performance than that of similar beamlines at other light source facilities.

During FY17-18, it is also planned to pursue the development of 'in-situ' diagnostics and metrology schemes and methods requiring minimal or no perturbations to existing optical schemes of beamlines, based on forward-simulations of partially-coherent radiation propagation and inverse problem solving. This work will be combined with the "At Wavelength Metrology" activity.

The "virtual beamline" environment, complemented by special software libraries for simulating samples and detector effects, will also be used to simulate user experiments at NSLS-II beamlines. The priority will be given to coherent elastic scattering experiments (such as those that are performed at CHX, CSX, and will be performed at the SMI, and the future CDI beamline). However, simulation of (ultra-)high-resolution microscopy and spectroscopy experiments should be technically feasible and important as well. The main goals of such simulations are: determining optimal beamline settings for each particular experiment (e.g. optimizing radiation degree of coherence, spatial and spectral resolution, flux at sample) and determining relevant "apparatus functions" (i.e. "transfer" or "point-spread" functions) to be used at experimental data processing. This activity will allow for optimal preparation of the experiments, use of the beam-time more efficiently, as well as better processing / interpretation of experimental data.

These on-going and/or planned developments will benefit not only the NSLS-II, but also a number of ultra-low emittance synchrotron upgrade projects and X-ray free-electron laser facilities (and their experimental programs) in the US and elsewhere. To facilitate this, the methods and software developed at NSLS-II will be made available via the DOE repository and possibly in the open source format (if so authorized by the DOE).

Precision Engineering and Nanopositioning

Precision engineering, nanopositioning and nanometrology are the essential key elements of the NSLS-II integrative systems engineering approach for mission-oriented R&D, as complex instrumentation, nanoscale motion, sensing, control, positional and angular stabilities often determine the ultimate performance of cutting-edge x-ray optical elements. In addition to x-ray optics, all related experimental subsystems, such as sample positioning, beam-defining apertures and complete endstations also require high-precision positioning and stability in order to take full advantage of the x-ray optics or advanced coherence techniques such as ptychographic imaging. In order to meet such needs, NSLS-II has established a state-of-the-art nano-positioning laboratory during the NSLS-II construction project to pursue R&D in precision engineering, nanopositioning, feedback and prototype systems. This culminated in the multiple-award winning MLL scanning microscope at the HXN beamline, which delivers a world record 12 nm spatial resolution in a working X-ray microscope, utilizing in-house developed MLL nanofocusing optics.

Building upon the experience and expertise acquired during the NSLS-II project, we will further develop advanced capabilities for precision engineering, positioning, actuation, manipulation, sensing and control at the nanoscale. Specific areas of future developments are:

1) Bonding of the MLL optics and novel positioning techniques using MEMS technology: The HXN beamline is delivering cutting-edge imaging results with unprecedented spatial resolution utilizing MLL nanofocusing optics. The HXN endstation employs state-of-the-art piezo-mechanical components and provides positioning accuracy down to a few nm. However, alignment of the two 1D MLL optics is a complex procedure which involves eight degrees of motion and requires nm-scale resolution and nm-scale long-term stability. To push the resolution even further and achieve a focal spot size of 5 nm and below, we are targeting a novel approach. Specifically, we plan to develop pre-aligned, bonded 2D MLL optics to minimize the number of motions needed for positioning of MLLs with respect to the sample. We will use microfabrication and Micro Electro Mechanical Systems (MEMS) to achieve this goal. This approach will scale down the size of the next generation microscope itself and in combination with optics development, will provide a route for imaging experiments with spatial resolution of 5 nm and below.

2) Sample manipulation apparatus for serial protein crystallography at full flux: the flux density of the MX beamlines at the NSLS-II surpasses the flux density of comparable beamlines around the world by orders of magnitude. The dramatic performance improvement offers great opportunities for scientific studies however the expected lifetime of samples falls into the ms range. In collaboration with the FMX team we are developing a novel, ultra-high-speed, high precision goniometer system to support scanning serial protein crystallography measurements and benefit from the flux density of the NSLS-II. The system will enable up to 5 Hz rotational speeds with simultaneous scanning frequencies on the order of 100 Hz, making it the fastest sample manipulation apparatus in the protein crystallography community.

3) Transmission X-ray Microscope endstation: The FXI beamline is currently under construction, and it targets tomographic imaging with a spatial resolution of 30 nm. The endstation is being developed in-house and will utilize some of the optical components available from a previous TXM microscope. The conceptual design of the high stability microscope has been developed. In collaboration with the FXI team detailed layout and some prototyping has been performed. Final design, construction, commissioning and optimization will occur over FY17–FY18.

4) Kinoform lenses microscope: kinoform lenses have been proposed and developed as an alternative way to provide x-ray focusing (see above). Recently, DOE M&S funds have been allocated for a construction of a prototype instrument suitable for testing and focusing experiments utilizing kinoform lenses. Design of the prototype instrument has been completed, components procured and fabricated, and the system will be assembled and tested. In FY17-FY18 it will be primarily stationed at the ISR beamline but since it is a stand-alone microscope, it can be moved to different beamlines or APS.

5) Support for emerging and existing beamlines utilizing standard mechanical metrology approaches. The development and performance of state-of-the-art beamlines requires very high precision mechanical systems. Achieving this level of precision requires an equivalent capability for the mechanical metrology instrumentation and resources. It is crucial to perform mechanical metrology of small mechanical setups, mechanical motion,

various large pieces of equipment (i.e., diffractometers, monochromators, mirrors, etc.), and vibrometry and its infrastructure prior to and after their installation. The requirements for mechanical metrology range from testing "simple" motion stages to measuring mechanical performance of complex instruments. Limited support in this area has been provided to date benefiting a number of existing and under-construction beamlines. HXN, SRX, SMI, SIX, FXI and other emerging beamlines benefited from this service. Finally, we plan to expand our services to support the development of multi-modal sample environments (in-situ, in-operando) to increase scientific impact of all beamlines at NSLS-II.

6) Development of automatic sample exchange systems: In order to increase scientific throughput of the highly complex microscopy systems developed at NSLS-II, it is of prime importance to enable automatic sample exchange protocol. This becomes especially critical when environmental conditions (temperature/pressure/magnetic field) are considered, to minimize down time due to equilibration processes prior to the measurements. We therefore plan to develop such systems. This will include sample storage containers, universal sample mounts, grippers, translation mechanisms, sensing and control algorithms. The prototype system will be developed for the ZP module of the MLL microscope at HXN and later transferred to other beamlines.

e. Detector Development

In this section we will discuss the ongoing developments in detector development.

The Detector Development group has been responsible for the development of a range of x-ray detectors in recent years, all of which are focused on the needs of NSLS-II beamlines.

First, the group has developed a suite of detectors for high-energy x-ray applications primarily for use at the XPD beamline. Specifically, two arrays detectors, one of CZT detectors and the other of fast scintillation counters have now been installed at the beamline, and are waiting for commissioning of the multi-crystal analyzer array by the beamline staff. With partial funding from DOE, we will construct several more germanium detectors with numbers of elements ranging from 64 to 384. The germanium microstrip detector with 384 strips, each 0.125 mm x 8 mm, is scheduled to be installed at XPD in July. Another detector, with 64 elements, is installed at the APS 6-BM for a program of energy-dispersive diffraction under the NSLS transition users program. That installation is just beginning to produce new science.

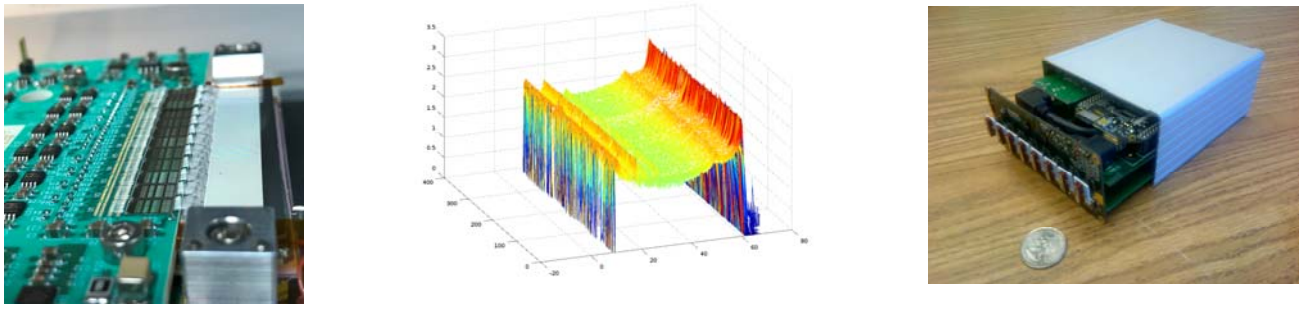

Figure 1.vi.e.1: (Left) photograph of the 384-strip germanimum detector showing the sensor and ASICs wire-bonded together. Middle: spectral from all 384 strips (241 Am source). Right: The CZT multi-detector showing its eight 16-element CZT sensors and its very compact readout circuitry.

Second, a silicon microstrip detector was designed built and installed at the IXS beamline where it is now running in the General User program and is producing science at that beamline.

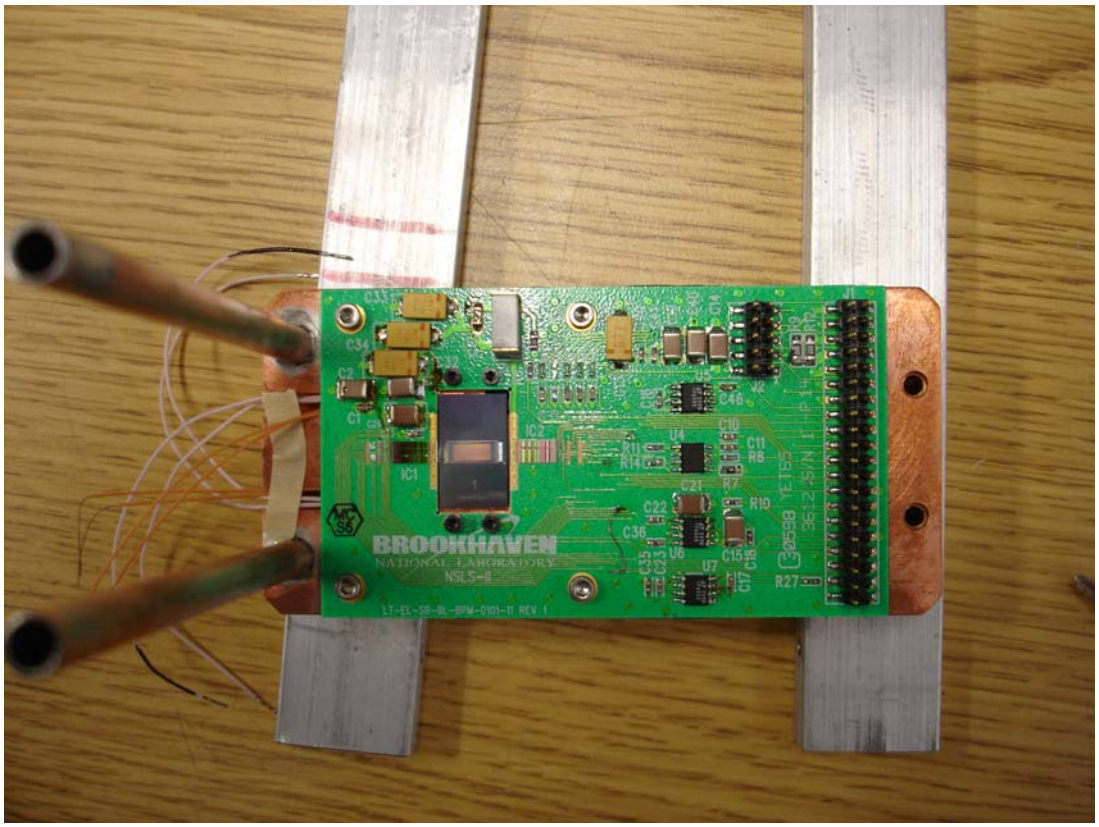

Figure 1.vi.e.2: This detector is a custom microstrip detector, designed to accept the six analyzer beams from the IXS analyzer. It consists of two arrays of 32 strips side-by-side. The six beams are steered to separate areas of the detector so they can be separately processed.

Third, a Maia detector was installed at SRX at the end of March 2017 and is presently undergoing commissioning before it will be transitioned into the General User program. The Maia system continues to be made available via our partner, CSIRO. One or two systems per year have been produced under a WFO agreement with them.

Presently, the Maia system energy resolution is limited to around 250 eV at 6 keV. The state of the art for a single detector is significantly lower than this. The focus of the group going forward is on improving this aspect of the system. A new ASIC has been produced which has lower noise than the existing system, but it needs a low-capacitance sensor to take advantage of its performance. An array of silicon drift detectors (SDDs) has been designed and a first attempt been made to fabricate it. The new device will have 384 SDDs, in a physical format which mimics the Maia. This is the largest array of SDDs ever proposed or realized, and is a challenging fabrication task. The first devices were functional, but suffered from a high leakage current which spoiled the energy resolution. A new batch is being fabricated with some modifications to help reduce leakage. These should be ready for testing by mid-June.

Fourth, we have been working on the VIPIC detector, a custom-designed detector for x-ray correlation spectroscopy. Following our successful demonstration of the 3D technology for this detector, a new project to build a 1Mpixel version has proceeded steadily. To date there have been no technological obstacles. However, some unexpected delays have occurred, largely originating with the vendor of the ASIC. We are monitoring their performance closely to avoid any further delay. The current schedule has the first pilot run of wafers being delivered in August 2017 at which point they will be assembled and tested. If they work as designed, the full production run can then be initiated. This chip will be the first pixel detector ASIC which can be completely seamlessly tiled on all four sides due to its novel design.

Fifth, we have developed an economical 4-channel electrometer designed for readout of small electrical currents (e.g. photoemission from slits and beam position monitors). This has proved very successful, with over 90 units deployed to date. A second version which can handle larger currents has just been deployed at the CMS beamline. It has more capabilities than the original, including the ability to connect directly to the NSLS-II timing system, thus facilitating the adoption of time-stamp coordination of diverse measurements, and providing DC outputs to facilitate the implementation of closed-loop feedback of optics and to bias a detector.

Figures 1.vi.e.3: These two instruments provide complementary resources for current measurement. The smaller unit to the left provides high precision measurements at the picoamp range, while the larger unit to the right accepts currents from microamps to milliamps, and provides outputs for detector bias and closed-loop feedback.

Sixth, the development of a spectroscopic imaging detector (HEXID) continues, though at a lower priority than the other developments. It will cover the energy range of ~2keV – 20keV. In conjunction with this development, a novel optical system is being designed which will allow achromatic full-field imaging of an x-ray-fluorescing sample.

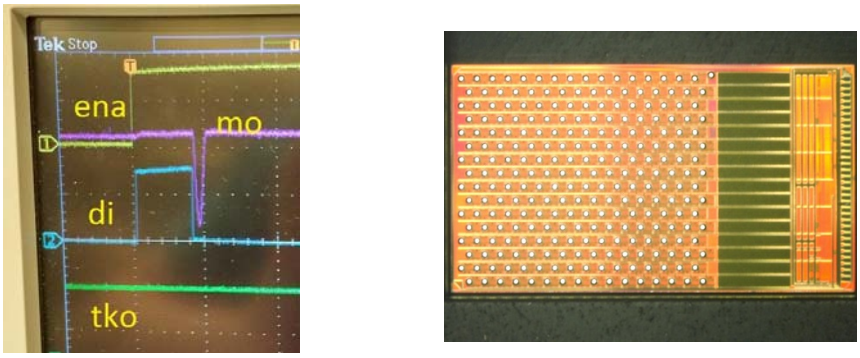

Figure 1.vi.e.4: The oscilloscope trace on the left show some of the controls signals for the HEXID chip, and a pulse (labeled "mo") which shows that the channel amplifier is working properly. The micrograph on the right shows the ASIC, with solder bumps ready for attachment to a sensor.

Finally, a very fine-pitch (20um) strip detector is being made for the ISS beamline, for use on the Von Hamos spectrometer. The hope is to achieve ~1um spatial resolution by exploiting the charge-sharing between adjacent strips to calculate a charge centroid, photon-by-photon in real time. Readout will re-use much of the hardware developed for the germanium detector project.

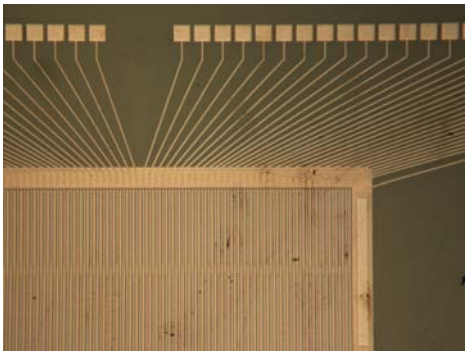

Figure 1.vi.e.5: A micrograph of the 20um pitch microstrip detector for the ISS Von Hamos geometry spectrometer to be mounted on the endstation chamber. The sensor has 128 strips, read out by four of our new MARS spectroscopy chip.

1.vii Scientific Staff Research Funded by the Facility

Below is a brief description of scientific staff research funded by the facility (research accomplished and proposed).

a. Accelerator Division

BASSI, GABRIELE

Research Accomplishments: Bassi is leading the program for analysis and suppression of beam instabilities related to collective effects and RF fields. A recent accomplishment is an analytical treatment of the coupled-bunch instability for arbitrary beam filling patterns. The theory was benchmarked with SPACE code simulations for the case of a varied gap in the uniform filling pattern[1]. Next, he completed a comprehensive study of microwave instabilities at NSLS-II. This work included analytical, numerical, and experimental studies of the intensity-dependent increase of the beam energy spread above the microwave instability threshold. Lastly, he analyzed and improved the beam loading compensation scheme and developed a useful software tool for online monitoring of the beam synchronous phase.

Proposed Research: In the future, Bassi will continue his work on the analysis of collective effects. This research is relevant to stable operations of NSLS-II, as well as for development of the future generation of storage rings. Bassi will continue his studies of beam dynamic effects caused by a 3rd harmonic cavity, which is planned for installation in the NSLS-II Storage Ring. Bassi also plans to develop and run his SPACE code and K. Ohmi's BBSS code, both on the Accelerator Physics Cluster and on the BNL Institutional Cluster, where 200k core hours of computing time have been recently allocated for his project. Lastly, Bassi will explore possibilities to establish collaborations with computational science experts, both onsite (Computational Science Department) and offsite (Stony Brook University).

BLEDNYKH, ALEXEI

Research Accomplishments: Blednykh's current research is focused on achieving a high beam current in NSLS-II. Several steps towards reaching 500 mA average current have been completed: 1) characterization of the vacuum components overheating, 2) measurement of beam instability thresholds, and 3) a study of the stabilizing effect of positive chromaticity in combination with the transverse feedback system. Blednykh also studied collective effects and beam instabilities, completing a comprehensive analysis of the low-frequency impedance of undulators and wigglers[2]. Lastly, Blednykh has completed an impedance optimization of the IR-chamber for the MET and FIS infrared beamlines at NSLS-II. The analysis of the microwave instability required that he update the longitudinal impedance model for NSLS-II.

Proposed Research: Blednykh will continue leading the program to increase the NSLS-II beam intensity to the project goal of 500 mA. He will carry out theoretical and experimental studies of the microwave Instability, update the model of NSLS-II longitudinal impedance with more ID's installed, and develop the model NSLS-II transverse impedance by wake field simulations in a large frequency band. The latter two impedance models will be used for a collective effects analysis to compare with measured data. Blednykh will also work on the analysis of single bunch

current limitations in the NSLS-II Storage Ring and study the feasibility and limitations of increasing the NSLS-II beam current beyond 500 mA.

CHENG, WEIXING

Research Accomplishments: Cheng's research has resulted in a set of state-of-the-art diagnostic tools, which are essential for NSLS-II operations and for future machine developments, and include: 1) a bunch-by-bunch feedback system routinely used to suppress transverse instabilities and provide advanced beam diagnostics with bunch-by-bunch capability, 2) optical diagnostics including a synchrotron visible-light monitor and X-ray pinhole camera, 3) improvements of the current digital beam position monitor (BPM) electronics, and 4) improvements in fill-pattern monitors, current monitors, and profile monitors.

Proposed Research: As the NSLS-II storage ring moves forward to higher current and lower emittance operations, Cheng's major effort will be directed to studying collective effects and beam dynamics utilizing various diagnostics tools. He will continue developing new beam diagnostics to better characterize/improve the NSLS-II machines.

CHOI, JINHYUK

Research Accomplishments: Choi is developing the NSLS-II Accelerator Database, ensuring the inclusion of all required information. He was also involved in the equipment failure analysis, which is very important to improve the NSLS-II operational reliability.

Proposed Research: Choi will be focusing on calculating active envelopes analysis, injector optimization and development of AD database.

GUO, WEIMING

Research Accomplishments: Guo developed linear and nonlinear lattice corrections via betatron phase advance. For the linear lattice, this approach is complimentary to the present methods; however, the proposed technique out-performs the other methods in nonlinear tuning due to improved measurement precision, and a more systematic approach that optimizes all the nonlinear constraints.[3]

Proposed Research: Guo will study the integration of the time-dependent Hamiltonian and apply it to the 3-dimensional models of magnetic field. The modeling method could be applied to the NSLS-II insertion devices to include more nonlinear terms than the current kick-map method. It can also be used to model the nonlinear effects in RF cavities and magnet edges.

HIDAKA, YOSHITERU

Research Accomplishments: Hidaka measured the impact on beam dynamics of the current strips on Elliptically Polarized Undulators (EPUs). Preliminary results indicate improvement in the dynamical aperture, but the measured correction field produced by the current strips differs from the prediction. The cause for this discrepancy is still under investigation as is dynamical fine-tuning of the current strip correction currents. Another topic of Hidaka's research is the calibration of a linear lattice model for the NSLS-II Storage Ring with a new turn-by-turn-based

fast characterization/correction code, which he developed, called DTBLOC (*Driving-Terms-Based Linear Optics Calibration*). This code has been utilized for linear coupling corrections and generation of a coupling feed-forward table as well as for multiple linear lattice corrections during energy down-ramp of the NSLS-II Storage Ring. Hidaka has successfully demonstrated single-shot measurements of tune-shift with amplitude by utilizing gated turn-by-turn and bunch-by-bunch data. This method eliminates data corruption from shot-to-shot noise and machine drift compared to conventional amplitude-dependent tune shift measurements.

Proposed Research: Hidaka will develop a method of creating a nonlinear local orbit bump. Creating even a simple local orbit bump becomes more difficult as lattices are getting more nonlinear. This technique will be useful for NSLS-II and it will be particularly important for new light sources with round beams to discover potential injection issues. Hidaka is planning a feasibility study with particle tracking, followed by the experimental demonstration of a new single-shot simultaneous linear and nonlinear lattice characterization method using truncated power series and gated turn-by-turn data with strategically-placed multiple bunch trains. If successful, this method would enable estimation of position offsets for sextupoles, beam position monitors (BPMs), and possibly quadrupoles, in addition to estimation of quadrupole and sextupole strength errors and BPM gain/roll errors. Use of a truncated power series representation, instead of direct tracking, allows inclusion of decoherence effects, which will be particularly useful for high-chromaticity lattices. Additional types of measured datasets may also help improve accuracy or reduce degeneracy for fitting parameters as dispersion, chromaticity, and gated turn-by-turn data with different closed orbits by changing corrector settings or quad strengths.

HIDAS, DEAN

Research Accomplishments: Hidas authored the *Open Source Code for Advanced Radiation Simulation* (OSCARS - http://oscars.bnl.gov) software package, which is open source, licensed, and freely distributable, allowing scientists and industry access to complex synchrotron radiation calculations in a simple environment. Notably, OSCARS has the advanced capability to calculate power density distributions from charged particle beams passing through arbitrary magnetic field configurations on arbitrary 3-dimensional structures. It was also designed to take advantage of the most advanced computing technologies to-date including grid/cloud computing, multi-threading on an advanced supercomputer, and Graphical Processing Units (GPUs). Hidas has also been performing numerical simulations of the radiative properties of insertion devices at NSLS-II.

Proposed Research: Hidas plans to make several additions and improvements to his OSCARS code including: improved wiggler approximation algorithms and Gaussian beam convolutions for fast estimates, brightness curve calculations, and advanced tessellation for 3D geometries. Hidas will participate in upgrades of the magnetic measurement facility to improve its on-the-fly measurement accuracy by reducing mechanical vibration and investigating sources of electromagnetic noise. Hidas will also be involved in the magnetic measurement of future insertion devices to streamline and significantly improve the measurement and data analysis in the laboratory.

PODOBEDOV, BORIS

Research Accomplishments: Podobedov has been contributing to a precise determination of the synchrotron ring vacuum chamber impedances by measuring extremely small current-dependent tune-shifts. Recent improvements in the NSLS-II beam position monitoring signal processing, make it possible to measure the difference between the betatron tunes of two (or more) individual bunches simultaneously stored in the ring with an accuracy of 10^{-6} or better. Performing this measurement for bunches of unequal charge enables the precise determination of the transverse kick factors, and, with separately measured bunch length, the coupling impedances of the ring vacuum chamber. Podobedov also achieved a quantitative understanding of beam loss and radiation patterns during NSLS-II beam dumps. NSLS-II has developed a beam containment system, which concentrates electron beam loss due to accidental beam dumps into the heavily shielded injection straight location, as well as measures the charge lost with Cherenkov monitors. The goal is to make the system capable of providing a reliable quantitative measure of the localized charge loss, as well as useful diagnostics for injection optimization and beam dynamics studies. Boris is focusing on studying beam orbit stability and is leading NSLS-II beam stability taskforce called by NSLS-II director.

Proposed Research: Podobedov will continue an experimental study of Touschek lifetime in the ultra-low emittance regime. This regime is presently reachable at NSLS-II without any hardware modifications, by lowering the electron beam energy. Moreover, NSLS-II damping wigglers provide a unique "emittance-control knob" for precise emittance studies. Podobedov will attempt to demonstrate the lowest horizontal emittance ever reached at storage ring light source, lower than 0.1 nm. Taking advantage of the ultra-low emittance regime, he will attempt to experimentally confirm (or prove wrong) the expected exponential increase in Touschek lifetime at ultra-low emittances. In addition to the Touschek lifetime, he plans to study the intra-beam scattering effect, which is a potential showstopper for reaching the lowest emittance. He will further pursue his studies of fast-ion instability and other ion-related effects, which are predicted to be a lot more significant at lower emittance. He will then explore the benefits of ultra-low emittance, lower energy spread, and high coherence for the (mid-to-soft) X-ray and UV beamlines (esp. CSX, CHX, ESM), and create a "high-coherence beam probe" for beamline optimization. Lastly, Podobedov will study wakefields of hard-to-model accelerator components.

SMALYUK, VICTOR

Research Accomplishments: Smalyuk and co-workers completed the following projects. 1) They experimentally crosschecked the performance, capabilities and limitations of several techniques for linear optics corrections.[5] 2) They developed a fast and precise AC *Linear Optics from Closed Orbits* (LOCO) technique based on a sine-wave beam excitation via fast correctors to improve the precision and decrease the measurement time of the LOCO method.[6] 3) They studied crossing half-integer resonances to achieve a non-standard approach to lattice design for circular accelerators and studied the coupled-bunch instability of the low-frequency quadrupole impedance.[1,2] 4) They analyzed beam-induced vacuum chamber heating, which was helpful to understand the heating mechanism and to find an optimal thickness of the metal coating. 5) They studied microwave instabilities by measurements of current-dependent energy spread using a synchrotron light monitor together with beamline spectra. 6) They developed a beam-based model

of broadband ring impedance[7] and a new technique of local impedance measurement using an AC orbit bump.

Proposed Research: Smalyuk will continue the AC LOCO development including measurement of sextupole offsets. He will continue the studies of overheating of the ceramic chambers and the studies of microwave instabilities. Smalyuk will carry out research on possible reasons for the discrepancy between computed impedance budgets and beam-based measurements. He will also use his new technique of local impedance measurement to measure the NSLS-II impedance distribution and will explore the possibility of 100 MeV beam injection in the Booster, which will improve the NSLS-II reliability in a case of a klystron failure.

WANG, GUIMEI

Research Accomplishments: Wang led the measurement of NSLS-II beam emittance and lifetime with damping wigglers[8]. Together with the NSLS-II RF group, she has developed novel RF phase jump tools, which are very effective for studies of NSLS-II longitudinal beam dynamics and has made key contributions to the experimental studies of crossing half-integer resonances. Her experiments at NSLS-II resulted in the conclusion that it may be unnecessary to confine the chromatic tune footprint between the resonance stopbands, this is a new non-standard approach of lattice design for circular accelerators.

Proposed Research: Wang's proposed research topics include: development of a model-independent online technique for lattice optimization; further improvement of the RF phase jump tools and its application to studies of longitudinal beam dynamics; experimental study of 3-rd order nonlinear resonance at NSLS-II, contribution to the program on achieving high average current.

YANG, XI

Research Accomplishments: Yang led the development of a fast LOCO code using sinusoidal beam excitation with fast correctors.[6] 15-nm beam position monitor (BPM) precision was achieved; a factor of 2 to 5 reduction in the residual beta-beating and dispersion errors was demonstrated. Simultaneously driving 23 correctors at different frequencies has been tested with similar BPM precision.[6] Yang developed and tested a new lattice correction technique based on independent component analysis (ICA) of turn-by-turn BPM data. Simultaneous linear optics and coupling correction by the ICA tool has been demonstrated at NSLS-II with similar precision of BPM calibration and residual error of linear lattice compared to the standard LOCO technique[9]. The software is ready to release. Yang also worked on theoretical studies of advanced undulator radiation sources in collaboration with FERMI at ELETTRA.

Proposed Research: In the future, Yang will work on implementation of a new algorithm of interference noise reduction for the AC LOCO data processing. A one to two orders' of magnitude reduction in noise-to-signal ratio is expected. She will make the AC LOCO software with the multiple frequency excitations ready for distribution. Yang will apply it for finding offsets of sextupoles. She will continue simulations and experiments on NSLS-II Injector optimization and Booster 100 MeV injection.

YU, LI-HUA

Research Accomplishments: Yu developed a new method of nonlinear lattice optimization by square matrix[10]. The method is used to improve the NSLS-II operational lattice by either increasing the dynamic aperture, or reducing the sextupole strength, so the system will be less sensitive to orbit motion.

Proposed Research: Yu will continue to work on the square matrix method to develop a theory for solving the nonlinear resonance problem using the square matrix. He will also proceed with implementation of his frequency interference method to the AC LOCO program and improve precision so that LOCO can be used to distinguish between nearly degenerate quads. Yu will continue work on orbit fast-feedback and correction to improve the precision of fast to slow correctors shift, enable orbit correction slowly without disturbing orbit, and allow changing insertion devices with minimum orbit perturbation. Lastly, Yu will perform research to find a new way to measure tunes for very large amplitude orbit changes.

b. Photon Science Division

ABEYKOON, MILINDA

Research Accomplishments: Abeykoon and co-workers reported reliable data acquisition and calibration protocols for the electron pair distribution function (ePDF) technique. This paper will immensely help the future users of this technique[11]. Abeykoon and co-workers also reported: 1) controlled synthesis methods and structural studies of ultrathin Europium Oxide Nanoplatelets shedding light on to their structure-property relationships[12]; 2) synchrotron-based diffraction experiments coupled to Rietveld and pair distribution function (PDF) analyses to understand the formation of NaGdF4:Yb:Er up-converting nanocrystals in organic media[13]; 3) the emergence of robust superconducting order in single crystal alloys of $TaSe_{2-x}S_x$ ($0 \leq \times \leq 2$)[14]; 4) the electronic structure, electric and thermal transport properties of $Ru_{1-x}Ir_xSe_2$ ($x \leq 0.2$) semiconductor[15]; 5) the electron doping effects by Ni in $K_xFe_{2-\delta-y}Ni_ySe_2$ ($0.06 \leq y \leq 1.44$) single crystal alloys, showing that a small amount of Ni (~ 4%) suppresses superconductivity below 1.8 K, inducing insulating spin glass magnetic ground state for higher Ni content[16]; 6) a detailed study to understand the mechanism, macroscopic and atomic level properties of $HoAl_3(BO_3)_4$ system, which shows a large magntoelectric effect[17]; 7) a detailed study on structure-property relationships in the novel double perovskite, Pb_2MnTeO_6 [18]; and 8) a detailed structural study on the multifunctional material, CoOOH using Rietveld and pair distribution methods;[19] Lastly, they used magnetometry and Mössbauer spectroscopy techniques to explore the magnetic properties, and X-ray and electron pair distribution methods to study the crystal structure of magnetic spinel ferrites, MFe_2O_4 as a function of particle size[20].

Proposed Research: Develop a strong user science program at the PDF beamline. Science program includes, but is not limited to: structural studies of fuel-cells in action, battery electrodes and electrolytes under real operating conditions, supercapacitors, nanoparticles with interesting optical properties, and many drugs in the discovery pipeline that have limited solubility in the crystalline state, theory driven synthesis of novel materials, catalysts under real operating conditions, and strongly correlated materials under magnetic fields in the temperature range (5-500) K. Probing the structure-property relationships in novel materials using combined techniques

(Ex. PDF and IR) will provide unique experimental input for the complex modeling approach (in collaboration with BNL's computer Science Initiative and Columbia University)

BAI, JIANMING

Research Accomplishments: Bai and co-workers advanced the following projects: 1) They used in situ synchrotron X-ray diffraction to study the solvothermal synthesis of $LiMn_{1-x}Fe_xPO_4$ cathode materials. The study revealed different reaction mechanisms of $LiFePO_4$, $LiMnPO_4$ and their solid solution. An intermediate phase was identified in the synthesis process of $LiFePO_4$ which is the key to understand the reaction mechanism[21]. 2) Using in situ synchrotron X-ray diffraction, spectroscopy and image techniques, they realized a structure tracking-aided design of the synthesis protocol of $Li_3V_2(PO_4)_3$, a cathode material with excellent cycling stability and rate capacity. The study revealed that the solvothermal treatment is a crucial step leading to an amorphous intermediate with local structural ordering resembling that of final product[22]. 3) Bai and co-workers conducted in situ studies of synthesis reactions and the associated structural ordering in preparing $LiNiO_2$ and the Co-substituted variant, $LiNi_{0.8}Co_{0.2}O_2$. The work gained insights into synthetic control of the structure and electrochemical properties of Ni-rich layered oxides[23].

Proposed Research: Developing new electrode materials of high energy density and power density is critical for the next-generation batteries. Preparing new electrode materials with synthetic control of phases and electrochemical properties is desirable for battery applications but hardly achievable without knowing how the synthesis reaction proceeds. We propose to use in situ synchrotron X-ray techniques (XRD, PDF, XAS and image) to realize structure tracking-aided design of new materials and the synthesis protocols. We will seek collaborations with theoretical groups to combine the strength of the in situ techniques and the ab initio prediction in exploration of the reaction pathways in various processes of materials synthesis, such as high temperature solid reaction, hydro-solvothermal synthesis, ion-exchange, and microwave synthesis.

BOUET, NATHALIE

Research Accomplishments: Bouet's research is mainly focused on the development of multilayer-based X-ray optics and in particular on the multilayer Laue lenses (MLL). Specifically, she led the efforts on the fabrication of these optics as well as the definition of the appropriate metrology processes for their evaluation prior to X-ray testing. Main accomplishments in the past three years include: 1) development of MLL optics for hard X-rays nanofocusing: wedged MLL[24,25], very large aperture MLL[26-29] and monolithic MLL optics[30], 2) contributed to the development of test patterns based on multilayers for characterization of metrological systems[31,32], 3) development of 1D ion beam figuring system for X-ray mirrors fabrication[33-35] 4) fabrication of multilayer optics for Diagon assemblies (ESM and SIX beamlines). Her research has been recognized by several awards: A R&D100 award in 2015 her work on multilayers for characterization of metrology tools (joint award with ABeam Technologies Inc., Argonne National Laboratory and Lawrence Berkeley National Laboratory) and in 2016 by both a R&D100 award and a Microscopy innovation award for her work on MLL (joint award with nanopositioning and HXN teams of NSLS-II).

Proposed Research: The MLL development will continue, focused on wedged MLL fabrication for sub-10nm focus and high efficiency optics, in collaboration with the Hard X-ray Nanoprobe beamline team as well as development of the monolithic MLL in collaboration with the nanopositioning team. R&D efforts and NSLS-II beamline support on thin film-based and in particular multilayer-based optics and optical components will be continued as well.

CAI, YONG

Research Accomplishments: As part of their research efforts in developing the science programs for the IXS beamline at NSLS-II, Cai and co-workers advanced the following projects on phonon dynamics in a number of material systems using high-resolution inelastic x-ray scattering and simulations: (1) The polyamorphic transition in GeO_2 induced by applied pressure was studied by examining the phonon dispersion in the materials using IXS and compared with ab initio computation. The work clearly identified the observed changes associated with the known coordination changes in the structure. The high sensitivity of the phonon dispersion on the coordination gave clear evident on the pressure boundary where the structural transformation took place[36]. (2) On DPPC lipid membranes, the observed phonon-mediated density fluctuations (phononic gaps) were linked to the creation of transient pores that facilitate passive transport of small molecules across the membrane[37]. (3) A short review was published examining the high frequency dynamics of simple disordered systems[38]. (4) In addition to the study of phonon dynamics, Cai and co-workers examined possible approaches to improving the energy resolution of the IXS beamline to 0.1 meV. The focusing monochromator concept examined provides some degree of energy resolution tuning with very high efficiency that adds to the flexibility of the beamline operation if implemented[39]. The imaging analyzer concept proposed by Yuri Shvyd'ko will be a likely choice for the spectrometer to reach 0.1 meV[40].

Proposed Research: With the NSLS-II IXS beamline in general user operation, Cai and co-workers' research effort will focus on to improving and upgrading the performance and data efficiency of the IXS spectrometer at the 1 meV resolution. At the same time they will develop a user science program utilizing the strength of the IXS beamline on complex soft matter systems with mesoscopic inhomogeneity and high pressure sciences. In parallel, they will continue the research and development effort in improving the energy resolution and performance of the IXS beamline, aiming at the ultimate 0.1 meV resolution goal.

CARR, G. LAWRENCE

Research Accomplishments: Carr and co-workers developed specialized instrumentation for synchrotron infrared beamlines and explored the use of near-field infrared nanospectroscopy at ALS beamline 5.4. Results include:1) infrared nanospectroscopy to characterize the local plasmonic response of gold nano-islands in thin films spanning percolation; 2) magnons and electro-magnons in multi-ferroic $DyFeO_3$ studied by spectroscopic infrared ellipsometry[41]; 3) plasmonic effects of gold embedded in glass investigated by optical spectroscopy[42]; 4) a system for stabilizing the infrared beam from a synchrotron source developed and tested[43]; 5) a broadband quarter-wave retarder for synchrotron far-infrared spectroscopy developed and used to characterize electron cyclotron resonance and exciton internal transitions in GaAs at magnetic fields up to 10T[44].

Proposed Research: Research will continue to focus on instrumentation advances for synchrotron infrared beamlines while the first infrared beamline at NSLS-II is under construction. Planned research includes further development of high-speed, long wavelength detectors as required for aperture-less infrared near-field spectroscopy and the study of nanomaterials using the capabilities at ALS beamline 5.4. Once an infrared capability has been restored at NSLS-II, research will focus on emergent materials under extreme conditions (*T*, *B* and *P*) as well as multi-ferroics and 2D electronic systems. The long wavelength capability of the MET infrared beamline should also allow the study of novel operating modes of the NSLS-II storage ring.

CHEN-WIEGART, YU-CHEN KAREN

Research Accomplishments: Chen-Wiegart and co-workers 1) studied environmentally induced chemical and morphological heterogeneity of zinc oxide thin films[45], 2) studied the effect of Ni content on the morphological evolution of Ni-YSZ solid oxide fuel cell electrodes[46], 3) observed the microstructural evolution of Ni- yttria-stabilized zirconia solid oxide fuel cell anodes[47], 4) conducted in situ Transmission X-Ray Microscopy of the lead sulfate film formation on lead in sulfuric acid[48], 5) probed three-dimensional sodiation–desodiation equilibrium in sodium-ion batteries by *in situ* hard X-ray nanotomography[49], 6) investigated the precipitation and surface adsorption of metal complexes during electropolishing by theory and characterization with X-ray nanotomography and surface tension isotherms[50], 7) visualized the electrochemically driven solid-state phase transformations using operando hard X-ray spectro-imaging[51], 8) understood the critical factors of the 3D microstructural formation in hybrid conductive adhesive materials[52], and 8) established early science commissioning results of the Sub-micron Resolution X-ray Spectroscopy Beamline (SRX) in the field of Materials Science and Engineering[53].

Proposed Research: Chen-Wiegart is exploring new research areas to: 1) develop and characterize the process and its mechanism of three-dimensional printing of novel batteries; 2) investigate the complex structure of functional materials that are used for higher density energy storage and conversion in lithium sulfur (Li-S) battery with sulfur-metal sulfide as a hybrid cathode; 3) develop a novel class of nano-/meso-porous metal thin films via metallic dealloying methods and to investigate their process-structure-property relationship via operando multi-modal synchrotron methods; 4) understand the microstructures of pores and their effects on degradation of complex composite media in cultural heritages; 5) establish computational analysis tools, using data mining and statistical correlation approaches, to address the challenge in analyzing complex data collected by multi-modal synchrotron research approach; and 6) partnering with industries, utilize cutting-edge in situ X-ray tools to investigate practical processes in manufacturing, such as silver sintering and anti-corrosion surface treatment.

CHU, YONG

Research Accomplishments: Chu and co-workers: 1) developed high resolution nanofocusing X-ray optics, called multilayer Laue lenses [24,25,28,30], 2) developed X-ray microscopy instruments[54-57], 3) developed X-ray microscopy techniques[8,29,58-60], 4) performed X-ray imaging research using the developed scientific capabilities of the HXN beamline [61,62].

Proposed Research: Ultrahigh-resolution X-ray imaging is a rapidly growing field with a huge potential scientific impact in many disciplines; in particular the microscopy capabilities of the

Hard X-ray Nanoprobe Beamline are unique. We propose to develop advanced imaging techniques and perform collaborative research with the beamline users.

CHUBAR (TCHOUBAR), OLEG

Research Accomplishments): Chubar and co-workers: 1) contributed, by physical optics calculations and optimizations, to development of new beamlines at NSLS-II[39]; 2) contributed to the commissioning of NSLS-II storage ring[63,64] and X-ray beamlines[55,65,66] by analyzing and benchmarking their actual performances against simulations; 3) developed an efficient method for spectrum-based alignment of In-Vacuum Undulators (IVU) and applied it at several NSLS-II beamlines (SRX, CHX, SMI) in collaboration with the beamline teams; this resulted in improvements of the beamline spectral performances; 4) introduced IDBuilder code for construction-stage optimizations and tuning of Insertion Devices (ID), which he developed earlier while working at SOLEIL, to the NSLS-II ID Group, and contributed to in-house magnetic assembly and shimming of several NSLS-II undulators using this code (refurbished X25 for NYX, EPU57 for SIX, EPU105 for ESM)[67]; 5) continued support and practical applications of Radia 3D magnetostatics code that he developed earlier while working at ESRF[68]; 6) contributed, by magnetostatic and synchrotron radiation calculations, to R&D on eRHIC accelerator project in the scope of collaboration with Collider-Accelerator Division of BNL[69].

Proposed Research: High-accuracy physical-optics based simulations and optimizations are very important for the most complete and efficient use of the high X-ray brightness and coherence offered by NSLS-II, and, even more so, by emerging new ultra-small-emittance multi-bend achromat type storage ring sources, as well as current and future X-ray free-electron lasers. Only such calculations can allow for optimal design of new beamlines and development of correct specs / tolerances on X-ray optics for such sources. It is therefore proposed to continue development of new, and improvement of already implemented (in SRW code) physical optics calculation methods enabling simulations with fully- and partially-coherent radiation beams, and to dedicate special efforts to high-accuracy calculation and benchmarking of the impact of optical imperfections on beamline performance. The forward-simulations are planned to be reinforced by special optimization and inverse problem solving routines. This will facilitate numerous applications of the SRW code, such as optical design of new sources and new beamlines (~5 new beamlines are planned to be developed for NSLS-II), development of new simple-to-use optical diagnostics and 'in-situ' metrology methods, simulation of complete user experiments in such areas as coherent scattering and high-resolution microscopy, and "bridging" of these simulations with experimental data processing. A currently-active general user proposal at CHX beamline, as well as advanced commissioning beam time at other beamlines, will be used to support this R&D. It is proposed to continue R&D on new IDs (such as SAGU) and advanced magnetic tuning methods, and to continue development and support of the IDBuilder and Radia codes for these and other applications.

CUNSOLO, ALESSANDRO

Research Accomplished: Cunsolo and co-workers: 1) performed high-pressure IXS measurements and parallel Density Functional Theory calculations on vitreous germania, demonstrating that a poly(a)morphic transition at about 9 Gpa leaves a clear fingerprint on phonon-like excitations[36]. 2) In an IXS investigation of a lipid membrane above and below the main transition temperature, they showed that collective motions of hydrocarbon tails facilitate

the passive molecular transport across the bilayer plane[37]. 3) They jointly used Inelastic Neutron Scattering and MD simulations to probe the dynamics of a prototypical hydrogen-bonded alcohol (liquid methanol), and observed striking analogies with liquid and supercooled water. These results challenged the broadly accepted assignment of anomalous dynamical properties of water to the tetrahedral symmetry of the hydrogen bond network[70]. Aside from these research achievements, a few review articles have been published by the same group to discuss literature IXS results on: water[71], noble gases[72] and, more generally, liquids with a different degree of dynamic and structural complexity.[38]

Proposed Research: In the close future the group will continue the collaboration with external groups focusing high frequency dynamics of networked (hydrogen-bonded) systems. Furthermore, IXS investigations are planned on materials undergoing a polyamorphic transition and or in extreme thermodynamic conditions as high/low temperatures and high pressures. Another research area of key interest for the group is the high frequency dynamics in moderately quantum systems (liquid Ne, H_2 and D_2) and highly quantum ones (Bose-Einstein condensate, superfluids, etc.).

DIMASI, ELAINE

Research Accomplishments: DiMasi and co-workers worked with industrial collaborators to analyze high throughput SAXS data from several hundred unique mixtures of anionic and amphoteric surfactants, compounds integral to the commercial production of "green" personal care products. A specific finding is that the surfactant micelles, which produce the desired physico-chemical properties, can be reliably tuned by addition of NaCl, but only in comparatively monodisperse and homogeneous formulations, highlighting the challenges for scaling-up using more common and cost effective commercially available surfactants. The work is published as a Research and Development report.

Proposed Research: High throughput multi-sample studies share many of the same requirements as studies that map heterogeneous samples. It is crucial to relate structure to function over a broad range of closely related conformations, formulations, degrees of structural order, and concentration gradients, to name a few of many possible variables that can be effectively probed by GI-SAXS/WAXS. DiMasi will ensure that the SMI beamline can effectively serve the many users whose work fall into these categories, and actively recruit and assist them.

DOORYHEE, ERIC

Research Accomplishments: Dooryhee and co-workers advanced the following projects: 1) Detailed synchrotron-based diffraction experiments were carried out to understand the formation of NaGdF4:Yb:Er upconverting nano-crystals (UCNCs) in organic media and to investigate their crystal structure[13]. UCNCs constitute an important class of nanoscale materials due to their capacity to convert near-IR photons into near-UV or visible light. 2) Hollandites are an intriguing class of sorbents, catalysts, and energy storage materials with a tunnel structure permitting one-dimensional insertion and de-insertion of ions and small molecules. A 7-fold increase in delivered capacity for $Li/Ag_xMn_8O_{16}$ electrochemical cells observed upon a seemingly small change in silver content (x changing from 1.1 to 1.6) led to a characterization of the structure and defects of the silver hollandite material.[73] 3) The local structure of as-deposited (*i.e.*, amorphous) and crystalline $FeSb_3$ films, was studied for gaining insight into the stabilization of the metastable

skutterudite $FeSb_3$ phase. This study illustrated how the local structure of amorphous precursor films could be analyzed by using the PDF technique.[74] 4) Synchrotron-based X-ray diffraction and small angle X-ray scattering measurements were used to characterize highly embrittling nm-scale Mn-Ni-Si precipitates that develop in irradiated steels at high fluency. These steels are used in permanent nuclear reactor structures that are exposed to a damaging flux of neutrons from the adjacent core. Precipitates lead to severe embrittlement that is not accounted for in current regulatory models.[75] 5) Lastly, based in part on the previous study, Dooryhee and co-workers outlined the benefits of an automated, high-throughput robotic system designed for the structural characterization of radioactive samples at the X-ray Powder Diffraction beamline of the NSLS-II.

Proposed Research: Dooryhee's research will use the unique capabilities of the X-ray Powder Diffraction (XPD) beamline of the NSLS-II to address the nation's scientific challenges in hydrogen storage, CO_2 sequestration, advanced structural ceramics, catalysis, nuclear engineering and materials processing. The scientific grand challenge is to obtain robust and quantitative (micro)structural information, not only in the ground state at ambient conditions, but also *in situ* or *operando* with varying temperature, pressure, magnetic/electric/stress field, chemical environment. Therefore Dooryhee will continue to collaborate on a range of topics that build upon the diffraction tools and methods that Dooryhee and co-workers are developing at the NSLS-II. Several collaborative projects are underway with XPD user groups that cover such topics as nuclear and/or irradiated materials, energy storage, catalysis, synthesis, extreme environments. Dooryhee will strive to support the research program at the NSLS-II in two major areas: 1) *in situ* synthesis (*e.g.*, high temperature solid state growth, colloidal nanoparticles from solution, flash sintering of ceramics/oxide materials, nucleation & growth of MOFs, and microwave-assisted synthesis) and 2) i*n situ* structure evolution (*e.g.*, catalysis, oxidation reduction reactions using gases, hydrogenation reactions, gas adsorption and separation, and cycling of energy-storage devices). Theory and experiment can be integrated in a closed loop in exploratory syntheses, where theory can identify theoretical desired materials that are thermodynamically stable, and *in situ* XPD synthesis could then be used to pinpoint the feasible synthetic routes. This new approach has great potential to accelerate materials discovery.

DVORAK, JOSEPH

Proposed Research: Dvorak's research involving the ex-situ metrology of gratings, particularly with regards to the detailed characterization of groove placement and its effect on partially coherent synchrotron beams will continue. In addition, work on the development of novel optical schemes will continue, especially with regards to high throughput and high resolution instruments.

EHM, LARS

Research Accomplishments: Ehm and co-workers investigated the adsorption mechanism of xenon and krypton in metal organic framework structures by a combination of *in operando* X-ray diffraction and advanced computational modeling.[76] Furthermore, Ehm compiled a review article on the high pressure synthesis and properties of multiferroics with Gilioli from CNR-IMEM, Italy.[77]

Proposed Research: Future research will follow two directions: 1) Determination of atomic structure, crystallization, and sorption properties of nanomaterials in operando at non-ambient

conditions. The focus will be on sorption/ion-exchange of highly radioactive strontium, iodine, and cesium on crystalline silicotitanates and monosodium titanate nanomaterials and 2) investigation of the formation mechanism of CO_2 clathrate compounds in marine sediments. Can the substitution of methane by carbon dioxide in clathrate structures lead to a carbon neutral energy source.

EHRLICH, STEVEN

Research Accomplishments: Ehrlich and co-workers measured structural distortions in a $Ni_{0.6}Co_{0.4}TiO_3$ ilmenite oxide solid solution at low temperatures using powder X-ray diffraction.[78]

Proposed Research: Proposed projects include: complete the QAS beamline and coordinate its commissioning and operation; optimize beamline performance and provide for efficient data collection, including minimizing setup and data acquisition time; work on combining XRD, conventional and quick XAFS at QAS, providing the capability to do time-resolved studies of structural changes, such as in chemical transformations and phase transitions, using both techniques on a variety of time scales; increase data collection rate and simultaneous collection of additional data, such as gas flow and composition, IR and Raman; optimize the beamline for catalysis and battery research programs; and work to provide additional capabilities including a gas handling system integrated with data acquisition software.

FLUERASU, ANDREI

Research Accomplishments: Fluerasu devoted the majority of his time to the Coherent Hard X-ray (CHX) Beamline project at NSLS-II. The CHX beamline has achieved first light in November 2014 and the following two years were dedicated to balancing between finishing building the beamline endstation, advancing the technical commissoning[66] and developing an active user program. Fluerasu and co-workers developed efficient data analysis capabilities for X-ray Photon Correlation Spectroscopy and X-ray Speckle Visibility Spectroscopy and deployed these capabilities at the CHX beamline.[79] Fluerasu wrote book chapters on the structural dynamics of materials probed by X-ray photon correlation spectroscopy[80] and on X-ray photon correlation spectroscopy for the study of polymer dynamics[81].

Proposed Research: Fluerasu and co-workers will: 1) finalize the CHX project at NSLS-II, start a vigorous user program at this beamline and transit the research program described here to this new beamline; 2) continue studies of structural dynamics in complex colloidal suspensions; and 3) focus on understanding the interplay between nano- and meso- scale dynamics and their macroscopic properties (e.g. rheology).

FUKUTO, MASAFUMI

Research Accomplishments: Fukuto and co-workers advanced the following projects: 1) They demonstrated the feasibility of using in-situ transmission small- and wide-angle X-ray scattering (SAXS/WAXS) as a local probe for heterogeneous structures at liquid surfaces, based on measurements on Langmuir monolayers formed on water meniscus against a vertically immersed, hydrophilic Si substrate. Their study also proposed a novel concept of using a vertical X-ray beam to enable scanning transmission X-ray scattering measurements on horizontal, stationary liquid surfaces.[82] 2) Using in situ X-ray reflectivity (XR) measurements on a series of bulk alkane-water

interfaces, they demonstrated that the oil-water interfacial widths are nearly consistent with the prediction by the capillary wave theory, and that the e-density depletion at the oil-water interfaces is significantly less than that observed for the interface between water and methyl-terminated self-assembled monolayers. This result is important to understanding the nature of the "hydrophobic gap" at the hydrophilic-hydrophobic interfaces.[83]

Proposed Research: Research will focus on three areas 1) in situ X-ray scattering studies to understand and control self-assembly of engineered virus-like particles at liquid interfaces and in bulk solutions; 2) in-situ X-ray scattering studies of polymer nanocomposite structures under processing conditions as well as thermodynamic and kinetic control of structural formation driven by phase separations and thermal fluctuations; 3) development and enhancement of SAXS/WAXS and GISAXS/GIWAXS capabilities at the CMS beamline, with emphasis on (i) improving sample and data throughput, (ii) expanding the portfolio of in situ sample environments, and (ii) implementing real-space reconstruction methods such as micro-probe and tomorgraphic SAXS/WAXS.

GHOSE, SANJIT

Research Accomplished: Ghose and co-workers advanced the following projects: 1) They measured the adsorption and separation mechanism of radioactive inert gases Xe & Kr in Metal Organic Frame works (MOFs) and characterized the structure of new types of MOFs with enhanced separation capabilities[76,84] 2) Metal−semiconductor hybrid nanoparticles (NPs) such as Au-InAs offer interesting synergistic properties, leading to unique behaviors that have already been exploited in photocatalysis, electrical, and optoelectronic applications. A fundamental aspect in the synthesis of metal−semiconductor hybrid NPs is the possible diffusion of the metal species through the semiconductor lattice. In this work Ghose and co-workers used a post-synthesis room-temperature reaction between $AuCl_3$ and InAs nanocrystals (NCs) to form metal−semiconductor core−shell hybrid NPs through the “reversed Kirkendall effect”.[85] 3) They used synchrotron-based X-ray diffraction and small angle X-ray scattering measurements to characterize highly embrittling nm-scale Mn-Ni-Si precipitates that develop in irradiated steels at high fluency. These steels are used in permanent nuclear reactor structures that are exposed to a damaging flux of neutrons from the adjacent core. Precipitates lead to severe embrittlement that is not accounted for in current regulatory models.[75] 4) XPD beamline at NSLS-II provides high-flux high-energy X-rays at tunable energies. This capability not only helps in measuring diffraction from complex materials in operation, but also in measuring materials in which it’s difficult to separate the phases due to contamination of the container. To separate the diffracted signals of the actual materials and the container one needs a slit system designed appropriately to do this job. Recently, Ghose and co-workers developed a spider-web slit system and tested it at NSLS-II. The slit system could be used to get diffracted signals from embedded samples in the bulk with 100 micron resolution.[86] This work is filed for a patient.

Proposed Research: Ghose’s research will use the unique capabilities of the X-ray Powder Diffraction (XPD) beamline of the NSLS-II to address the nation’s scientific challenges in synthesis and enhance efficiency of energy materials, CO_2 sequestration, safe & efficient extraction of methane, storage of hydrogen, advanced structural ceramics, catalysis, nuclear engineering and materials processing. His proposed research will take the advantage of high energy and high flux X-rays at NSLS-II to go beyond the “cook & look” approach but to

characterize samples *in-situ* or *operando* with varying temperature, pressure, magnetic/electric/stress field, chemical environment. Therefore Ghose and co-workers will continue to collaborate on a range of topics that build upon the diffraction tools and methods that they are developing at the NSLS-II. Several collaborative projects are underway with XPD user groups that cover such topics as nuclear and/or irradiated materials, energy storage, catalysis, synthesis, extreme environments. Ghose will strive to support the research program at the NSLS-II in two major areas: 1) *in situ* synthesis (*e.g.*, high temperature solid state growth, colloidal nanoparticles from solution, flash sintering of ceramics/oxide materials, nucleation & growth of MOFs, and synthesis by electrical flash-sintering) and 2) *in situ* structure evolution (*e.g.*, catalysis, oxidation reduction reactions using gases, hydrogenation reactions, gas adsorption and separation, and cycling of energy-storage devices). Theory and experiment can be integrated in a closed loop in exploratory syntheses, where theory can identify theoretical desired materials that are thermodynamically stable, and *in situ* XPD synthesis could then be used to pinpoint the feasible synthetic routes. This new approach has great potential to accelerate materials discovery.

HU, WEN

Research Accomplishments: Hu became an assistant scientist at NSLS-II in June 2016. She is performing collaborative scientific research on nanomaterials and charge correlations in high temperature superconductors using soft X-ray diffraction.

Proposed Research: Hu plans to continue work on method developments and applications on scientific issues using the X-ray diffractive imaging method including: 1) development of soft X-ray ptychography/CDI in both transmission and Bragg mode and its applications; 2) developing methods to measure and analyze X-ray wavefront and retrieve beam profile using the 23-ID-1 beamline; and 3) carry out science experiments in close collaboration with users and CSX team.

HUANG, LEI

Research Accomplishments: Huang and co-workers advanced the following projects: 1) They studied the at-wavelength metrology and phase retrieval techniques.[87,88] 2) They investigated and compared various existing wavefront reconstruction methods and proposed some new wavefront reconstruction methods for three-dimensional shape reconstruction from gradient data.[89-92] 3) A new approach for synchrotron mirror metrology based on phase measuring deflectometry was studied and explored.[93-95] 4) They worked on ion beam figuring with several height and slope metrology tools to reduce the surface figure error of mirrors and to demonstrate the concept of using ion beam figuring to improve the quality of X-ray mirrors.[33-35] 5) They proposed a new scheme to control X-ray bimorph deformable mirrors with several actuators during their inspection in optical metrology laboratory. Based on the measured slope values from the slope-measuring tools, the surface curvature errors can be estimated with a dedicated algorithm and the mirror can be driven to the expected shape.[96-98]

Proposed Research: The slope metrology tools in the NSLS-II optical metrology lab are well-developed and give very promising results for X-ray mirror inspection. Compared to the slope measuring technique, the height metrology tools based on interferometry are not fully utilized. We propose to use the white light interferometer assisted by a slope sensor (triple beam interferometer, or autocollimator) to demonstrate the capability of measuring 1D height profile of

X-ray mirrors with high spatial resolution and with sub nm accuracy. In addition, we propose a new stitching interferometer platform which can handle about 1-m-long X-ray mirrors, which will be a very important instrument in the optical metrology laboratory, as we can compare the results from slope metrology tools with this new height metrology tool. In parallel, the work already initiated on at-wavelength metrology, phase measuring deflectometry, ion beam figuring, and active x-ray optics will be pursued.

HUANG, XIAOJING

Research Accomplishments: Huang's research involves the development and application of diffraction-based imaging techniques using a nano-focused X-ray beam. His work on ptychography development includes partial coherence correction[99], on-the-fly operation[59], and probing the third dimension[100]. His work on X-ray lens characterization includes wedged multilayer Laue lenses[25] and monolithically bonded multilayer Laue lenses[30]. Huang contributed to X-ray instrument development.[57] His research also includes applying X-ray imaging techniques to study: surface structure using crystal truncation rods[101], pressure-induced strains[60], the nanostructure of chromosome[29], and trace element distribution in root tissue[61]. He contributed to a technique review on X-ray imaging of nano-materials[102] and also published conference proceedings on the hard X-ray nanoprobe beamline[54], lensless dynamic imaging[103], undulator performance[55], multilayer Laue lens fabrication[24], and instrument for nano focusing[28].

Proposed Research: Huang will focus on integrating phase-retrieval based imaging methods into the multi-modality microscopy system at the Hard X-ray nanoprobe beamline for enhanced spatial resolution and detection sensitivity. He will develop and mature the experimental approach for high throughput 3D and in-situ studies.

IDIR, MOURAD

Research Accomplishments: Since 2010, Idir has been leading the NSLS-II Optical Metrology Group. The main focus of Idir's research effort targets development of optical metrology system capable of ultimate characterization of state of the art X-ray mirrors (sub nm rms shape error and sub 100 nrad rms slope error). As a group leader of the NSLS-II Optical Metrology Group, Idir supervised the entire R&D effort developed by the NSLS-II Optical Metrology Laboratory from slope measuring instruments to stitching interferometry. He also coordinated all the mirror metrology for NSLS-II beamlines and provided the necessary guidelines/information/calculations for mirror specifications to beamline scientists to support the facility mission. Idir and co-workers advanced the following projects related to mirror fabrication and mirror metrology: ion beam figuring[87,88], 2) mirror phase measuring deflectometry[93-95], slope measuring mirror metrology[33,104], and adaptive mirror metrology[96-98].

Proposed Research: Idir's research will continue to focus on the development of state of the art optical metrology tools and fabrication of diffraction limited x-ray optics. The R&D optics program will follow 3 main themes: 1) continue investigations and instrumentation development for ultra-high accuracy X-ray mirror metrology, 2) continue at-wavelength metrology system development, and 3) continue promoting and developing a dedicated Testing Beamline at NSLS-II.

KHALID, SYED

Research Accomplishments: Khalid and coworkers have done extensive research work in the field of catalysis, Fischer Tropsch Synthesis[105-109], catalysts and catalysis reactions, and in the field of water gas shift[110-112]. His work has a major impact on the search for energy resources under environmentally friendly conditions. The catalysts used for these reactions have hydrogen and hydrocarbons as their product. The toxic gas carbon monoxide can be converted to water and less harmful carbon dioxide. In addition to this research work he also collaborated in battery research to explore better catalysts for cathodes and anodes and electrolytes for making more powerful, safer, and longer lasting batteries. X-ray Absorption Spectroscopy is now a matured and well established technique to explore the atomic and electronic structure of materials. His research work resulted in two invited talks.

Proposed Research: Khalid will continue collaboration with different groups working in the field of catalysis and batteries to come up with less expensive catalysts and nano-scale catalysts to improve the Fischer Tropsch and Water Gas Shift reactions for energy production. X-ray absorption and other techniques will be used to characterize these materials.

LEE, WAH-KEAT

Research Accomplishments: Lee's primary role is to lead the development, from design to operations of the Full-field X-ray Imaging (FXI) beamline, including scope, schedule, cost and technical design. The overall design of the beamline was advanced under the NEXT project and construction phase is under the BDN project. The beamline design was presented at a SPIE conference and published in its proceedings.[113] Lee developed simulation software to enable design of a new TXM. He designed a new transmission x-ray microscope (TXM) for FXI, to replace the turn-key Xradia TXM which is very limiting and cannot take advantage of the NSLS-II photon flux. Furthermore, the proprietary data acquisition software does not take advantage of the new and powerful NSLS-II data acquisition/management/analysis system. The new TXM design is much more open and flexible, and will enable the FXI to take advantage of new advances in x-ray optics and detectors. Lee also published work based on previous collaborations at the Advanced Photon Source.[114-117]

Proposed Research: The immediate focus is to commission the FXI beamline and the new TXM instrument. Early science commissioning should begin in 2018. Two immediate priorities are: (a) establish collaborations for X-ray optics development (eg; zone plates, capillaries) and (b) development of general use sample environment cells. A major concern is the survivability of the X-ray zone plates at FXI because they will be subject to much higher beam intensities. Thus, in the near term, a source of 30 nm zone plates is needed. Furthermore, for the long-term development and advance, it is essential to collaborate with a group that is interested and capable of producing the next generation optics. FXI will be a world-leader in high speed TXM – enabling imaging of dynamics at the 30 nm spatial resolution level. Thus, the ability to control and change the sample environment will be essential.

LI, RUIPENG

Li joined NSLS-II in January, 2017.

Proposed Research: Li and co-workers will design and explore the *in situ* solution processing of nano materials in microfluidic chips to control the kinetic assembly process. This is a research opportunity opened by the 11BM beamline at NSLS-II. Li and co-workers will also develop instrumentation for additive manufacturing of soft materials for *in situ* X-ray characterization. This is a research opportunity opened by the 11ID and 11BM beamlines.

MAZZOLI, CLAUDIO

Research Accomplishments: Mazzoli joined NSLS-II in November 2014, as part of CSX-1 team in the soft X-ray Scattering program. He took active part in the beamline commissioning; he is in charge of a principal part of the beamline development (nanofocusing implementation) and he routinely supports users operation and experiments. His interest is in electronic ordering and inhomogeneity and in particular on Charge Density Wave (CDW) dynamics in high temperature superconductors (HTSC).[118] He leads the scientific project on electronic ordering investigation in layered cobaltates by both elastic (REXS) and inelastic (RIXS) soft X-ray resonant techniques. He uses hard X-ray and neutron diffraction for the investigation of magnetoelectric and multiferroic materials[119-121] with potential application in information storage and low power consumption electronics.

Proposed Research: Strongly correlated electron systems (SCES) are among the most varied, complex and intriguing solid state systems in terms of electronic properties, ordering scales, inhomogeneity, segregation, separation and phase diagrams. Their competing interactions result in unique quantum behavior with potentially advanced application from power management and distribution to information processing, from advanced detectors to innovative actuators and multifunctional devices. For these reasons, Mazzoli will continue to investigate specific SCES showing colossal magnetoresistance, HTSC, exotic quantum and magnetic phases, dynamics and topologically protected phases by means of elastic and inelastic soft X-ray resonant techniques and hard X-ray and neutron diffraction. In particular, he will focus his attention in imaging of exotic magnetic phases and the determination of their dynamics with potential interest and application in spintronics and magnonics.

NAZARETSKI, EVGENY

Research Accomplishments: Nazaretski and co-workers advanced the following projects: 1) They developed and deployed a number of prototype systems for X-ray microscopy applications at NSLS-II [59] culminating in the construction of a Multilayer Laue Lens (MLL) microscope installed at the HXN beamline[57]. 2) Their developed instrumentation has been applied to address various scientific questions including chromosome imaging.[29] 3) Their development of various imaging instruments utilizing MMLs as nanofocusing elements stimulated development of monolithic 2D nanofocusing optics. A prototype 2D monolithic MLL optic achieved a resolution of 12x24 nm^2. [30]

Proposed Research): Based on the extensive expertise acquired during the development phase of an HXN MLL-based microscope, we will develop 1) full-field ZP-based imaging system for the

FXI beamline, 2) the test platform (scanning microscope) for testing and development of the kinoform lenses.

NORTHRUP, PAUL

Research Accomplishments: Northrup's primary effort in this period was the construction and commissioning of the TES Beamline 8-BM Microprobe. Northrup with collaborators: 1) developed a tender-energy (1-5 keV) microprobe for micron-scale X-ray fluorescence (XRF) imaging and X-ray absorption spectroscopy (XAS) in heterogeneous materials; 2) used, for the first time, *in-situ* XRF microscopy combined with microbeam XAS to directly probe the morphological and chemical changes of Li-S batteries during cycling[122]; 3) examined interplanetary dust particles to determine for the first time the distribution of light elements K, S, P, Si, Al and Mg, and the chemical speciation of P and S which were important nutrients for early life on Earth; 4) identified for the first time the production of natural organochlorines in marine phytoplankton[123]; 5) examined the grain-scale heterogeneity of P in soils, to help elucidate the origins of observed bioavailability vs. mineralization or leaching, to improve sustainability while reducing damage to ground- and surface waters, and 6) first-ever measurements established the applicability of Pu M-edge microspectroscopy and XRF imaging to study the chemistry and transport behavior of Pu in the environment.

Proposed Research: Focuses on TES beamline program development and commissioning, it includes: 1) using tender-energy microspectroscopy to elucidate the speciation and heterogeneity of trace elements in soils and sediments, with focus on a) nutrients important for biomass/biofuel productivity and sustainability, such as P, K, Ca, b) energy-related environmental contaminants such as U, Tc, and Pu, and c) biogeochemical cycling and processes, from the grain scale to the global scale; 2) technique-development for the application of and improved data-analysis of lighter-element EXAFS; 3) using *in-situ* tender-energy microspectroscopy to explore speciation and heterogeneity in dynamic energy-science systems such as batteries and fuel cells; and 4) characterizing the function and chemistry of catalysts and novel energy materials.

OCKO, BENJAMIN

Research Accomplishments: Ocko joined the NSLS-II staff in October 2015. Ocko and co-workers advanced the following projects: 1) X-ray reflectivity (XR) and atomistic molecular dynamics (MD) simulations provide new insight into the oil/water interface, the simplest liquid-liquid interface. For several oils (hexane, dodecane, and hexadecane) the XR shows very good agreement with a monotonic interface-normal electron density profile (EDP) broadened only by capillary waves. Similar agreement is also found for an EDP including a sub-Å thick electron depletion layer separating the oil and the water.[83] 2) They used temperature-dependent optical microscopy and interfacial entropy determinations methods to study surfactant-stabilized spherical alkane emulsion droplets that spontaneously adopt polyhedral shapes upon cooling while the interior and exterior remain liquid. The in-situ and coinciding ex-situ Wilhelmy plate measurements confirm the low interfacial tension, $\lesssim$0.1 mN/m, providing strong quantitative support validating the crystalline monolayer buckling mechanism.[124,125] 3) They utilized XR (NSLS/X22A) and grazing incidence scattering methods (NSLS/X22B) to study the structure of n-alkyltrichlorosilane self-assembled monolayers formed on the amorphous native oxide of silicon (100). Grazing incidence diffraction shows that the monolayers are composed of hexagonally packed crystalline-like domains with a lateral size of about 60 Å. Together, Bragg

rod and XR analysis show that ~12 of the CH_2 units are not included in the crystalline-like domains.[126]

Proposed Research: Despite the enormous interest and technological importance of liquid interfaces, their structure and morphology are poorly understood relative to those at the vacuum interface. This is a direct consequence of their challenging experimental conditions and the lack of appropriate methods. X-ray scattering techniques provide the best methods for probing liquid interfaces, including interfaces in contact with air, a second liquid, and flat and nanostructured solids. Future plans include studies of surfactant/oil/water systems that are relevant to DOE's emerging energy-water nexus, the processing and drying of flexible hybrid electronics materials, and water filtration membranes prepared through interfacial polymerization at the oil/water interface. These studies will greatly benefit from the approved NSLS-II Polymer and Liquids Scattering (PLS) endstation/beamline.

PINDAK, RON

Research Accomplishments: Pindak and co-workers advanced the following projects: 1) They used crystal truncation rod measurements and the COBRA phase retrieval approach to discover the unexpected displacement of oxygen atoms in the CuO_2 plane of $La_{(2-x)}Sr_xCuO_4$ thin films under the application of enormous electric fields produced by a gated ionic liquid in contact with the films. Ionic liquid field-effect gating remains one of the most promising approaches to achieve high-Tc superconducting transistors.[127] 2) They reviewed two decades of discoveries made using polarization-analyzed tender X-ray resonant scattering at NSLS beamline X19A and provided a future outlook on new directions opened by the development of pixel array detectors and incident polarization controllers to the tender X-ray range.[128]

Proposed Research: Pindak and co-workers will explore the THz characterization of optical and acoustic phonon modes in liquid crystal phases at nanometer length scales as well as the control of these modes by external fields. This is a research opportunity opened by the 10ID beamline at NSLS-II. Pindak and co-workers will also develop instrumentation for the in-situ X-ray characterization of the kinetic processes underlying the 3D printing of soft and bio-nanomaterials using time-resolved X-ray techniques at 11ID and 12ID.

RUMAIZ, ABDUL K.

Research Accomplishments: As a physicist with the Detector group at NSLS II, Rumaiz has been responsible for the sensor development of a range of x-ray detectors. All of the group's developments are focused on the needs of NSLS-II beamlines. Rumaiz has also been involved with hard x-ray photoemission measurements with collaborators from NIST. The technique has been used to study band alignment in a variety of heterojunctions.[129,130] Rumaiz and co-workers also measured the potential build-up at the LAO/STO interface.[131] More recently, it was also shown that resonance high energy photoemission can be used to investigate charge transfer in metal oxide systems.[132]

Proposed Research: The energy resolution of the MAIA detector can be increased significantly by using a silicon drift array (SDD) instead of standard pin diodes. However, the design of SDD array is complicated and the current state-of-the-art is limited to few detectors at best. Rumaiz and co-workers are designing an array that will incorporate 384 SDDs which would be the largest

array of SDDs ever proposed or realized. The first batch of sensors were fabricated by the end of 2016. The first test showed all sensors working although with high noise. The problem has been isolated and a new batch is being fabricated with some modifications to help reduce leakage. There are also plans to start germanium sensor fabrication in-house. The proposed process would get away from lithium diffused contacts in germanium to more robust p+ implants. Rumaiz has also working with collaborators from the Instrumentation Division to develop microwave kinetic inductance detectors. Initially these detectors are designed for astrophysics application but we hope that with enough maturity of technology this will find application in synchrotron science.

SIDDONS, D. PETER

Research Accomplishments: As the leader of the Detector Development group, Siddons has been responsible for the development of a range of x-ray detectors. All of the group's developments are focused on the needs of NSLS-II beamlines as seen in the following examples: 1) The group developed a suite of detectors for high-energy x-ray applications primarily for use at the XPD beamline. An array of CZT detectors and an array of fast scintillation counters are also both available for experiments at the beamline. 2) A silicon microstrip detector was custom designed for the IXS analyzer and is producing science at that beamline. 3) At the end of March they will install a Maia detector at the SRX beamline and commission it. 4) An economical 4-channel electrometer designed for readout of small electrical currents (e.g. photoemission from slits and beam position monitors) has proved very successful, with over 90 units deployed. A second version which can handle larger currents has just been deployed at the CMS beamline. It has more capabilities than the original, having the ability to connect directly to the NSLS-II timing system, facilitating the adoption of time-stamp coordination of diverse measurements, and provides DC outputs to facilitate the implementation of closed-loop feedback of optics and to bias a detector.

Proposed Research:

1) The commercial germanium sensors currently available are not ideal, and plans to improve them are underway. 2) A very fine-pitch (20um) strip detector is being made for the ISS beamline, for use on their Von Hamos spectrometer. The hope is to achieve ~1um spatial resolution by exploiting the charge-sharing between adjacent strips to calculate a charge centroid, photon-by-photon in real time. Readout will re-use much of the hardware developed for the germanium detector project.

SMITH, RANDY

Research Accomplishments: Smith and co-workers advanced the following projects: 1) They developed a new method for examining protein structural changes in living cells using full-field synchrotron infrared imaging. This technique was applied to understand protein misfolding in genetic variants of amyotrophic lateral sclerosis (ALS).[133] 2) They designed and fabricated a sample cooling stage for X-ray fluorescence microprobe measurements of soft and/or hydrated materials to mitigate beam damage. They then looked at beam induced redox rates vs. temperature of both model complexes and real-world samples.

Proposed Research: Smith and co-workers are focusing on the following projects: 1) Continuing the develop of a sample cooling stage for X-ray fluorescence microprobe beamlines mitigating beam damage- a problem for modern microprobe beamlines with small and brighter beams that achieve very high flux densities. 2) as a member of the NSLS-II director appointed multimodal task force, identifying and needs and opportunities in combining modes of measurements and data analysis across multiple beamlines and lab-based measurements. 3) Setting up a semi-portable lab-based X-ray fluoresces microprobe using a tube source and polycapillary focusing for pre-beamtime sample surveying. 4) Designing and fabricating a split-channel mini-ion chamber suitable for the small x-ray beams at NSLS-II 5) Developing capability of correlating imaging data from multiple beamlines and lab-based imaging instruments.

SUVOROV, ALEXEY

Research Accomplishments: Suvorov's research is primarily focused on the development of advanced X-ray optics for high X-ray energy resolution techniques, like IXS. Suvorov and co-workers advanced the following projects: 1) They advanced a concept of a focusing monochromator. Improvement of the energy resolution of the IXS beamline down to 0.1 meV is a highly desired goal. However, this is a very challenging problem. It was shown that under certain conditions the energy resolution of 0.1 meV and beyond can be achieved with a high efficiency in a focusing monochromator setup. Spectral line of the focusing monochromator has much higher contrast compare to the conventional design.[39] 2) They numerically investigated a newly proposed IXS echo spectrometer under conditions close to a real IXS experiment. The echo spectrometer is a recently advanced concept of an IXS spectrometer which overcomes limitations in spectral resolution and weak signal of the IXS technique. However, factors like the finite geometrical dimensions of a sample, the scattering angle and monochromator energy detuning, can potentially impact the performance of the echo spectrometer and therefore worsen its energy resolution. The simulated scattering from a hypothetical sample demonstrated the ability of the echo spectrometer to maintain its high energy resolution in a wide range of varied parameters.[40] 3) Lastly, they analyzed the expected / simulated performance of the IXS beamline and compared it to experimental observations. The IXS is a photon hungry technique. The performed analysis identified potential sources of the intensity losses of the IXS beamline and the ways to eliminate them.[55]

Proposed Research: Further investigation of the IXS spectrometer designs allowing combination of high efficiency, high photon flux, and high energy resolution is important to studying mesoscopic dynamics in liquids, soft matter, and biological systems. The problem requires a complex approach with numerical simulations, theoretical analysis and experimental tests. With the spectrometer operation energy around 10 keV, this will create an opportunity for potentially high impact research. Another aspect of the problem is the data collection and analysis. The new designs may require additional treatment and analysis of the collected raw data. To do this, a specific software suite needs to be developed and tested. All of the problems mentioned above creates a vast field for future research activity.

TAPPERO, RYAN

Research Accomplishments: Tappero leads the development of the X-ray Fluorescence Microprobe (XFM) beamline at NSLS-II. He is also PI of the proposal submitted to DOE-BER to fund the construction of the X-ray Fluorescence Nanoprobe (XFN) Beamline. Tappero works to

develop novel synchrotron-based X-ray imaging methods, and to apply these tools to problems in the biological and environmental sciences. His research focuses on the transformation, speciation, and bioavailability of trace elements in soil and the rhizosphere, and the mechanisms of uptake, metabolism, and tolerance in higher plants as related to sustainable production of plant biofuels and remediation of contaminated lands. As a beamline scientist with broad research interests, he also pursues collaborations in energy science and catalysis, materials science, and nanoscience as well as the life and medical sciences. Tappero and co-workers studied: 1) the complex structural dynamics of nanocatalysts *Operando* conditions[91], 2) the life-limiting process of lithium primary batteries[134], and 3) a candidate therapeutic agent for treatment of intracerebral hemorrhage[135].

Proposed Research: Immediate goals are to finish construction of the NSLS-II XFM beamline and complete the Instrument Readiness Review (IRR). Related goals include characterization and technical commissioning of the XFM beamline, and the development of the first set of science experiments in collaboration with the user community and the beamline advisory team (BAT). Long term goals include continuation of instrument and technique development, continuation of research of relevance to DOE missions, further involvement with the design and deployment of imaging and microspectroscopy facilities at NSLS-II, and efforts to secure funding for the XFN Beamline and further its conceptual design.

THIEME, JUERGEN

Research Accomplishments: Juergen Thieme is the lead beamline scientist of the Sub-micron Resolution X-ray Spectroscopy beamline (5-ID). In this function, he works on the development of novel synchrotron radiation based X-ray spectroscopy and imaging methods, and on the application of these methods in a wide variety of scientific areas, focusing on environmental, nuclear, planetary, and geo-sciences. Together with cooperation partners he worked on topics in geomicrobiology, for instance looking into the inhibition of sulfidogenesis by tungsten, and the interaction of biofilms with their mineral substrates. He is co-investigator in the Solar System Exploration Virtual Institute (SSERVI) "Remote In-Situ and Synchrotron Studies for Science and Exploration (RIS4E)" funded by NASA and lead by Stony Brook University. Here, he is working on in-situ measurements of space weathering of minerals using a high-power laser at the beamline. The first industrial user coming to NSLS-II at all worked with him at 5-ID to study topics relevant for industry such as surface treatments[45]. Together with colleagues from the Nonproliferation and National Security Department he is working in the area of nuclear forensics, investigating forensic samples on uranium using XRF mapping and XANES spectroscopy, which is of high interest for IAEA and NNSA. He is working on Laboratory Analysis of Returned Samples (LARS), a program initiated by NASA. In addition to these activities, he worked in the frame of the Instrumentation Execution Plan Development initiative of NSLS-II on the conception and design of a soft X-ray transmission X-ray microscope (STXM).

Proposed Research: Novel methods for the SRX beamline include the combination of several contrast methods, e.g. X-ray fluorescence and micro-diffraction. This will allow for structural in addition to chemical information on the sub-micron and the sub-100nm scale. Furthermore, tomography in transmission and fluorescence will allow for morphological, elemental, chemical and structural information in 3D. And finally, using the coherence of the beam, ptychography is a novel method improving spatial resolution significantly even with existing beamline optics. A

continuation of the work at SRX implies outreach to the scientific community, clearing the path for state-of-the-art experiments in many areas of science, especially those of relevance to DOE missions. Collaborations with groups focusing on new battery materials have shown first results and shall be intensified. The industrial user has great interest in partnering with SRX to study relevant topics such as surface treatments in more detail. The existing (RIS4E) and aspired (LARS) collaboration with NASA will initialize the use of SRX and other beamlines at NSLS-II for studies in planetary sciences, aiming for experiments with Mars Return Samples as a highlight. Work on nuclear forensics, of great interest for IAEA and NNSA has shown first results and will be continued and widened. A continuation of instrument and technique development, aiming for a STXM beamline, will benefit many different scientific communities. Nanoscale, microscale and mesoscale microscopic imaging across NSLS-II beamlines will be pursued.

WALUYO, IRADWIKANARI

Research Accomplishments: Since joining NSLS-II staff in July 2015, Waluyo's activities have been focused on beamline and endstation commissioning at CSX-2 as well as user support. Through these activities and collaborations with users, she has contributed to research on 1) the surface characterization and the oxidation and reduction behavior of zeolite model systems using AP-XPS.[136-138] and 2) CO_2 hydrogenation on $Pt/CeO_2/TiO_2$ catalyst using AP-XPS.

Proposed Research: Waluyo's ongoing research activities are focused on in-situ soft X-ray spectroscopy studies of heterogeneous catalytic systems, particularly bimetallic catalysts. Bimetallic alloys are known to be more active and stable catalysts compared to individual metal components due to enhancements in their electronic and geometric structure resulting from the synergistic interactions between the two metals. In addition, through bimetallic catalysts, the use of an expensive but highly active metal such as platinum can be minimized by combining it with a cheaper, more abundant metal such as copper. Waluyo will use AP-XPS and XAS to study model bimetallic catalysts under realistic reaction conditions. This research is aimed toward characterizing catalytically active sites and elucidating reaction mechanisms in order to understand structure-function relationships that drive reactivity.

WANG, JUN

Research Accomplishments: Wang and co-workers advanced 1) an in-situ diffraction study of the high-temperature decomposition of t'-Zirconia[139], 2) a study of critical factors of the 3D microstructural formation in hybrid conductive adhesive materials by X-ray nano-tomography[52], 3) an in-situ transmission X-ray microscopy study of the lead sulfate film formation on lead in sulfuric acid[48], 4) the visualization of electrochemically-driven solid-state phase transformations using operando hard X-ray spectro-imaging[51], 5) a transmission X-ray microscopy study of the galvanostatic growth of lead sulfate on lead and the impact of lignosulfonate[140], 6) a synchrotron micro-scale study of trace metal translocation and distribution in Spartina Alterniflora root system in Yangtze River Intertidal Zone[141], 7) a fast and informative fitting method for XANES chemical mapping analysis (NNLSF)[142], 8) the theory and X-ray nanotomography / surface tension isotherm characterization of precipitation and surface adsorption of metal complexes during electropolishing[50], 9) 2D cross sectional analysis and associated electrochemistry of composite electrodes containing dispersed agglomerates of nanocrystalline Magnetite, Fe_3O_4[134], 10) the study of unexpected three-dimensional de(sodiation) equilibrium in sodium ion batteries by in-

situ hard X-ray nanotomography[49], 11) a synchrotron-based transmission X-ray microscopy study to quantify the abundance of magnetofossils at the Paleocene-Eocene boundary[143], 12) an in-situ X-ray nanotomography study of metal surfaces during electropolishing[144], 13) a characterization of cracks and their effects on the effective transport pathways in Ni-YSZ anodes after reoxidation using X-ray nanotomography[145], 14) an observation of the microstructural evolution of Ni- Yttria-stabilized zirconia solid oxide fuel cell anodes[47], 15) a three-phase 3D reconstruction of a $LiCoO_2$ cathode via FIB-SEM tomography[146], 16) effect of Ni content on the morphological evolution of Ni-YSZ solid oxide fuel cell electrodes[46], 17) a combined electrochemical and X-ray tomography study of the high temperature evolution of Ni-Yttria stabilized Zirconia solid oxide fuel cell anodes[147], 18) a synchrotron X-ray microfluorescence measurement of metal distributions in Phragmites Australis root system in the Yangtze River intertidal zone[148], 19) a study of the dispersion of nanocrystalline Fe_3O_4 within composite electrodes providing insights on battery related electrochemistry[149], 20) a study of the Cu^{2+}/Cu0 and Fe^{3+}/Fe0 redox couples in Li/$CuFe_2O_4$ using X-ray absorption spectroscopy demonstrating the reversibility of mixed transition metal oxides in Li-ion batteries[150], 21) the visualization of anisotropic-isotropic phase dynamics in battery electrodes[151], 22) an in-operando XRD and TXM study on the metastable structure change of $NaNi_{1/3}Fe_{1/3}Mn_{1/3}O_2$ under electrochemical sodium-ion Intercalation[152], 23) new insight into chemical reaction with in-situ 3D chemical mapping at nanometer scale[153], 24) a study to elucidate the irreversible mechanism and voltage hysteresis in conversion reaction for high-energy sodium-metal sulfide batteries[154], 25) a study to unravel the origin of irreversible capacity loss in $NaNiO_2$ for high voltage sodium ion batteries[155], and 26) a study that shed light on the lifetime of the solar nebula constrained by meteorite paleomagnetism.[156]

Proposed Research: continue research in energy materials using synchrotron X-ray techniques, especially, the transmission X-ray microscopy (TXM); continue working with collaborators on modeling and simulation of Li-ion batteries and Na-ion batteries with experimental data from TXM; continue working on industrial-related research with industrial scientists.

WIEGART, LUTZ

Research Accomplishments: Wiegart and co-workers have advanced the following projects: 1) They carried out commissioning and bench-marking experiments at the Coherent Hard X-ray (CHX) scattering beamline at NSLS-II. The focus of the work was the characterization of the source and beamline optics in terms of performance parameters, such as flux, focal spot size, transverse coherence, etc. Measurements were quantitatively compared to partially coherent wavefront propagation simulations in the SRW environment. The work contributes to the development of 'virtual beamlines', web-based beamline and experiment simulations mimicking the performance of the real corresponding beamline.[55,66] 2) They demonstrated three-dimensional coherent X-ray diffractive imaging of whole frozen hydrated cells.[157] 3) They developed coherent X-ray scattering methods and data analysis.[158] 4) Lastly, they demonstrated experimentally the technique of coherent amplification for meso-cluster scattering in the presence of a strong background.

Proposed Research: 1) Exploit the potential of time-resolved coherent scattering to measure and understand the relaxation dynamics of polymer-nanocomposites under external strain/mechanical deformation. Oscillatory strain of different amplitudes can be used to determine the microscopic irreversible deformations in the nanostructure at the onset of yielding. 2) 3D printing of

viscoelastic inks is an emerging technique for fabrication of 3D structures of functional materials by direct-write assembly. XPCS and other scattering techniques are ideally suited to investigate the far out-of-equilibrium processes during the deposition and curing of the inks.

WILKINS, STUART

Research Accomplishments: Wilkins and co-workers used resonant X-ray scattering and X-ray photon correlation spectroscopy to measure the remarkable stability of the charge density wave (CDW) in cuprate superconductors. These results showed that in both the superconducting state and the normal state and at all temperatures below the transition the CDW is static over serval hours[118]. Using nanolithography techniques combined with coherent resonant X-ray scattering Wilkins and co-workers also studied the return point memory effect of the CDW domains in a superconducting cuprate. What is surprising with these results is that the CDW domains are pinned to the lattice above the CDW ordering temperature in the low temperature orthorhombic phase of the material. Only upon warming above the structural transition into the high temperature tetragonal phase anneals the charge stripe domains – resulting in a different domain orientation upon re-cooling into the CDW ordered phase.

Proposed Research: In the quest to fully understand the behavior of quantum materials it is vitally important to understand the form and role that electronic textures show in defining the properties and response under external stimuli. Coherent soft X-ray scattering techniques are vital in imaging such electronic textures. The proposed research will extend the first initial experiments undertaken on a cuprate to understand the charge stripe domains and timescales and extend to other notable systems such as stripe ordered nickelates. In addition, instrument development and first experiments on using soft X-ray resonant scattering in a surface sensitive geometry will be undertaken. These experiments will be able to address how the electronic degrees of freedom behave at the surface of a correlated oxide material.[112]

WILLIAMS, GARTH

Research Accomplishments: Williams' research interests revolve around the fundamental physics of imaging. Over the current period, He has actively participated in theoretical and experimental aspects of the Linac Coherent Light Source's (LCLS) Single Particle Imaging (SPI) initiative. In this initiative, over 100 scientists collaboration to make the imaging of biomolecules through coherent diffractive imaging (CDI) a reality.[159,160] He co-authored an early history of LCLS.[161] He has continued to publish results from LCLS with his collaborators on a wide variety of topics including: protein crystallography[162,163] and related technologies[164,165]; high energy density and ultrafast materials science[166,167]; and atomic and molecular optics.[168,169] Additionally, he performed the first CDI experiment on the SRX beam line of NSLS-II in FY16. His contributions to the SRX beamline helped to make possible the publications resulting from that instrument.[45]

Proposed Research: As X-ray user facilities continue to provide increasingly bright X-ray sources for exploitation by scientists, Williams will continue to develop instrumentation, algorithms, and methodologies to maximize the scientific return from these. At NSLS-II, he will continue to develop the methodology on existing beamlines, such as SRX, and will lead the development of new instrumentation for CDI experiments. At LCLS, he will continue to provide

leadership support and technical expertise to ensure that the goals of single particle imaging will proceed as far as is possible with current technology. His primary target for CDI is currently amorphous metals, with an emphasis on time-resolved measurements of their structure as they undergo failure, which will be pursued at both facilities.

YAN, HANFEI

Research Accomplishments: Over the past three years Yan and co-workers have advanced the following projects: 1) They fully commissioned the NSLS-II hard X-ray nanoprobe beamline and demonstrated the multimodality imaging capability at a resolution of 15-nm, achieved by multilayer Laue lens (MLL). To date this is the highest scanning imaging resolution reported in hard X-ray regime. This achievement led to 2016 Microscopy Today Innovation Award and 2016 R&D 100 Award. 2) They developed a robust program based on the differential phase contrast mechanism to allow the reconstruction of the quantitative phase image in real time at the beamline, which greatly assist the viewing of nearly transparent samples with very weak absorption contrast. 3) They developed the MLL microscope with nm resolution and stability.[57] 4) They investigated the performance of wedged MLLs for higher efficiency and numerical aperture[25] and that of the bonded MLLs for reduced alignment complexity[30]. 5) They conducted theoretical studies on sample statistics of powder diffraction pattern from nanoparticles and its impact on data analysis.[170,171] 6) They utilized the high-resolution and multi-modality imaging capability of the MLL microscope to study distributions of trace metals in chromosomes[29], elemental distribution and nanostructures of solid-state sodium battery[62] and trace element distributions in spartina alterniflora root tissue during dormancy[61].

Proposed Research: There are growing demands for hard X-ray scanning microscopy tools that can achieve a higher spatial resolution and deliver more flux into the sample. We will continue the development of multilayer Laue lens for sub-10 nm focus and over 50% focusing efficiency.

ZHANG, YUGANG

Research Accomplishments: Zhang joined NSLS-II in May 2015. Zhang and co-workers advanced the following projects: 1) They used DNA-based polyhedral frames to organize Au nanoparticles into crystalline and open 3D frameworks. They employed synchrotron-based SAXS and observed a rich family of crystallographic lattices depending on the designed DNA-frame geometries. This developed approach will permit the rational assembly of nanoscale lattices through the design of the unit cell.[172,173] 2) They used Au-facet nanocrystals as a platform to reveal the oxygen reduction reaction (ORR) pathways on a series of Au crystalline planes. They found a full-range 4e ORR for the first time on gold [310] facets on ditetragonal nanocrystals. Combined with density functional theory calculations, they suggested that both the low-coordinated surface gold sites and the co-adsorbed surface water are responsible for this novel property. 3) Lastly, they developed a new X-ray scattering technique to extract valuable information, e.g., scatter's symmetry, from background-dominated samples. This technique relies on the coherent interfering sample with a designed strongly-scattering 'amplifier'.

Proposed Research: Active colloids have been one of the hottest emerging materials due to their potential applications in nano-machines, active assembly and drug delivery. Despite the large interest and tremendous research efforts, mainly offered by optical microscopy studies, the behavior of nanoscale colloids and collective dynamics in opaque suspensions and in porous

solids are still poorly understood phenomena. Zhang will use XPCS to probe the motion of active particles in liquids, polymer solutions and in highly architectured 3D nanoscale matrixes as well investigate their transport properties through ordered 3D matrix of channels. He will also study the evolution of active colloidal dynamics in glass/crystal forming systems.

ZHONG, ZHONG

Research Accomplishments: 1) Collaborating with Jianming Bai, John Parise and Don Weidner, Zhong was instrumental in the project led by Ron Pindak to design, build, and commission a new beamline at the Advanced Photon Source (APS) for energy-dispersive x-ray diffraction at the 6-BM-A. This was in partnership with the team led by Jonathan Almer and John Okasinski at the APS. 6-BM-A is currently used for research on energy storage devices and engineering materials.[174,175] 2) Along with Andrew Broadbent and team led by Daniel Fischer from NIST, he co-authored the FDR documents for both SST and BMM beamlines at the NSLS-II for soft- and hard-x-ray spectroscopy. 3) He participated in the R&D, design, construction and commissioning of a sagittal-focusing Laue monochromator for NSLS-II X-ray Powder Diffraction beamline led by Eric Dooryhee. 4) DEI, a synchrotron-based method invented at the NSLS for biomedical imaging, introduces selectivity for the angular deviation of x rays. Zhong continued investigation of DEI for soft-tissue imaging of tissue-scaffolding, breast imaging and lung imaging.[176] 5) Zhong developed a new dual-energy absorptiometry method for fat-muscle ratio measurement using radioactive source Am241.[177]

Proposed Research: 1) The first project involves the development of energy-dispersive X-ray diffraction and phase-contrast imaging at the HEX beamline at the NSLS-II. New development includes utilization of multiple element Ge detectors. The beamline will be used for research of batteries, engineering materials, and additive manufacturing. 2) DEI, traditionally a synchrotron-based method for biomedical imaging, introduces selectivity for the angular deviation of X-rays. Future research will include design and construction of a DEI system at the HEX beamlines. 3) X-ray optics R&D of Laue crystals in fundamental and practical aspects as applied to the optical design of the HEX beamlines.

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1.vii.i Scientific Staff Research Funded by Other Sources

Below we will provide a brief description of scientific staff research funded by the other sources (research accomplished and proposed).

a. Accelerator Division

BLUM, ERIC

Proposed Research: Blum and co-workers are currently studying means to reduce the emittance of the NSLS-II storage ring by as much as a factor of four. There will be two phases to this work. In the first phase an increase in the horizontal damping partition number introduced by displacing the beam orbit through the quadrupoles will be employed together with adjusted horizontal beta in the dipoles to reduce the emittance by a factor of two. The benefit of installing a Robinson wiggler will also be explored. In the second phase of the study, a 4-bend achromat lattice will be developed for further decrease of the horizontal emittance within the constraints of fewest storage ring modifications, lowest cost, and least downtime possible for implementation. In collaboration with NSLS-II ID group, Blum and co-workers will also explore novel insertion device designs using time and position dependent magnetic fields for fast spectroscopy experiments. Blum is also planning to examine the production of extremely high (exceeding 20 T) pulsed magnetic fields for magnetic scattering experiments.

Supported by BNL LDRD-17-015

YU, LI-HUA

Proposed Research: Yu and co-workers are developing a focusing beamline for an Ultra-fast Electron Diffraction (UED) facility. The goal is to achieve a focus point size of 50 μm with 50 pC and 10-20 μm for a charge of 1 pC, and take measurements of the beam size. X. Yang's contribution to the project includes: 1) Impact-T simulations of magnet lattice optimization, 2) re-optimizing magnet settings for focusing the electron beam transversely to the sample chamber, 3) development of the Gradient Method for multi-dimensional parameter optimization, 4) applying this method for machine tuning and optimization, and 5) laser system commissioning. V. Smalyuk worked on the design and commissioning of optical beam diagnostics. The optical system, currently being used to diagnose and tune the facility, includes CCD cameras with objective lenses, optical filters, controls and data processing software. The goal is to finish installation of the focusing beamline in July 2017, then start commissioning.

Supported by BNL LDRD-16-010

b. Photon Science Division

ANDI, BABAK

Research Accomplishments: Andi was part of the multi-institutional team that developed an Acoustic Droplet Ejection-Droplet on Tape (ADE-DOT) system that uses sound energy to eject as many as 120 sample containing droplets per second into an X-ray beam for time-resolved data collection on solution and crystalline protein samples. This new method was used to collect data on Photosystem II (PS-II), which exists in plants, algae, and some bacteria and is the source of oxygenic photosynthesis that sustains life on earth. Understanding the exact chemical mechanism of photon capture and oxygen release will have broad practical applications in energy efficiency and storage.[1] The feasibility of the method was tested on various protein solutions and crystals using a light-induced and or oxygen-induced initiation of a chemical reaction as well as its feasibility to collect simultaneous X-ray emission spectra and X-ray diffraction data on the same sample.[2]

Proposed Research: The new ADE-DOT method provides a robust and highly versatile sample delivery option that is suitable for multiple time-resolved data collection (diffraction and spectroscopy) at the same time and has been successfully deployed at X-FELS. We will establish how to deploy this technology at NSLS-II and will continue the development of ADE-DOT technologies for crystallographic, scattering and x-ray foot printing experiments. Initial experiments will be made with XFP and subsequently FMX & AMX.

Supported by NIH

ATTENKOFER, KLAUS

Research Accomplishments: Attenkofer and co-workers 1) used in-situ X-ray diffraction, X-ray fluorescence, and GI X-ray Reflectivity to study the growth and the solid state reaction chemistry of CsK_2Sb[3-5], 2) used time resolved X-ray and laser spectroscopy to study the correlation between charge transfer and configurational changes in molecular systems[6], 3) developed new X-ray optics[7], 4) developed new materials and coating techniques for advanced detection systems[8], and 5) evaluated X-ray metrology for reliability research in the field of photovoltaics.[9]

Proposed Research: SBIR supported research will continue on heterogeneous catalysis and materials growth by Atomic Layer Deposition.

Supported by NEXT Project and three DOE/SBIR grants

BISOGNI, VALENTINA

Research Accomplishments: Bisogni's research focuses on two main topics: 1) contributing to the design, assembling and commissioning of the high-resolution spectrometer for resonant inelastic X-ray scattering (RIXS) at the SIX beamline[10,11], with special focus on the sample manipulation system, the sample transfer system and the detector; and 2) studying the electronic ground state properties in artificial nickel-based thin films using soft x-ray spectroscopy techniques[12,13], as well as investigating fundamental properties related to spin and orbital arrangement in low-dimensional copper-oxide materials[14-16]. The results of these two research

topics have been presented at several international conferences and workshops. Bisogni also contributed to additional research studies in collaboration with: 1) T. Schmitt's group from Paul Scherrer Institute (Switzerland) on Fe-pnictides[17] and artificial cuprate/titanate heterostructures[18]; 2) M. Dean's group from CMPMSD at BNL on high-temperature superconducting cuprates.[19]

S*upported by NEXT Project*

CAI, YONG

Research Accomplishments: Within the currently funded LDRD program, Cai and co-workers focused their effort on the study of phonon dynamics in supercritical fluids and nanoparticle self-assemblies using inelastic x-ray scattering and molecular dynamics simulations: (1) the phonon dynamics in supercritical Ar were studied in which a universal link was established between the positive sound dispersion and the existence of transverse phononic modes, revealing the viscoelastic crossover mechanism.[20] The simultaneous disappearance of both effects at elevated temperature signifies the existence of the Frenkel line in supercritical fluids, where structural crossover was also observed for the first time using x-ray diffraction.[21] Furthermore, a strong localization of the longitudinal mode and the appearance of high-frequency transverse phononic gap were observed, providing further indications of the presence of two dynamic domains in the system.[22] The theoretical framework for the study of the thermodynamics of various states of matter was introduced[23], providing a unified approach to describe the thermodynamics of the pressure-temperature phase diagram in terms of phonon excitations. (2) The dynamics of 2D gold nanoparticle arrays in a water matrix was studied by molecular dynamics simulations and found to display a plethora of phenomena, including phononic energy gaps, Dirac-like crossings and anti-crossing of phononic bands of the sub-atomic network, allas a result of the interaction of the nanoparticles assemblies with the water matrix at the nanoscale.[24]

Proposed Research: In the remaining 6-month extension of the LDRD program, Cai and co-workers will explore the use of IXS to study phonon propagation in a range of complex soft matter systems with mesoscopic inhomogeneities, including nanoparticle assemblies, liquid crystals, block copolymers, and lipid membranes, with the aim to elucidate the fundamental aspects of sound propagation in these complex materials, which are responsible for heat transfer at the molecular scales.

Supported by BNL LDRD-15-031

CHODANKAR, SHIRISH

Research Accomplishments: Chodankar and co-workers continued to study density fluctuations in confined fluids using X-ray scattering. They combined X-ray scattering from colloid-filled channel arrays with first-principles inhomogeneous liquid-state theory in order to study the singlet and pair correlations of the most fundamental confined fluid.[25] Experiment and theory are in excellent agreement at the pair-correlation level, thereby providing the first quantitative experimental verification of the theoretically predicted anisotropic pair correlations of confined fluids. Chodankar as part of the LiX beamline team is also involved in specific areas of technical development, including a high throughput solution scattering set-up, time-resolved studies using a fluid mixer, and implementation of coherent diffraction imaging to improve the spatial resolution

in imaging experiments. The current development status of the beamline including the optical set-up and experimental capabilities are described in a beamline article.[26]

Proposed Research: As part of the experimental capability at LiX beamline, he is developing a microfluidic mixer in collaboration with staff from the Center for Functional Nanomaterials. The goal is to reduce both the mixing time and sample consumption.

Supported by NIH and DOE-BER

CHU, YONG

Research Accomplishments: Chu and co-workers developed an in-situ microscopy capability by constructing in-situ electrochemical cells. Two types of cells were developed. The first type enables TEM and X-ray measurements on a common sample. The second type is optimized for X-ray microscopy with greater flexibility. The in-situ cells they have developed are frequently used by the general users of the HXN beamline.

Proposed Research: Chu and co-workers will continue to actively deploy and develop the in-situ cells in the general user experiments at the HXN beamline. In doing so, these cells will be better tailored to the specific experiments, enabling greater scientific productivity at the beamline.

Supported by BNL LDRD-15-037

CHUBAR (TCHOUBAR), OLEG

Research Accomplishments: Chubar and co-workers 1) made important contributions to development of new web-based cloud-computing framework for X-ray optical simulations (Sirepo) and integration of the SRW code to this and other frameworks[27];* 2) contributed, by physical optics calculations using the new framework, to development of new instruments for light source facilities other than NSLS-II[28-30];* 3) continued R&D on the Segmented Adaptive-Gap Undulator (SAGU) for NSLS-II[31].**

Proposed Research: The results achieved in the development of the new web-based cloud-computing framework for X-ray optical simulations will be summarized in a comprehensive report of the DOE SBIR Phase 2 grant No. DE-SC0011237 (that was executed in collaboration with RadiaSoft LLC from April 2015 to April 2017) and in publications. A proposal for the Phase 2a extension of this project has been submitted to DOE, targeting further improvement of the simulation framework (Sirepo) for the development of new instruments / beamlines and simulation of complete user experiments, as well as multiple applications of this framework to light source facilities over the DOE complex (LCLS-I/II, APS(U), ALS(U), in addition to NSLS-II). In the area of development of new IDs, progress will be made on completing the final part of the BNL LDRD project on SAGU, including assembly and laboratory tests of a prototype 3-segment device, and preparation of an eventual follow-on R&D (that could possibly be covered from other sources or/and NSLS-II ops), including tests of the prototype with electron beam, and possibly development of final SAGU for several NSLS-II beamlines.

** Supported by DOE SBIR grant No. DE-SC0011237*

*** Supported by BNL LDRD-15-038*

CUNSOLO, ALESSANDRO

Research Accomplishments: In the first two years of the LDRD, Cunsolo and collaborators advanced the following projects: 1) They jointly used Inelastic X-Ray Scattering and Molecular Dynamics (MD) simulations to study high-frequency collective modes in highly supercritical Argon, discovering the presence of a thermodynamic line, which demarcates the boundary between liquid-like and gas-like domains of the supercritical phase.[20] 2) By combined X-Ray diffraction and MD simulation methods, they found that the crossing of such a thermodynamic locus in the supercritical phase, the Frenkel line, is accompanied by clear changes in the structural arrangement of a liquid.[21] 3) In another joint IXS and MD investigation of supercritical Ar, they discovered the presence of thermally triggered gaps in the sound propagation.[22] 4) A further IXS and MD work on Ar linked the formation of such gaps to the disappearance of viscoelastic effects in the spectrum of density fluctuations.[20] 5) Through a series of large-scale MD simulations of a two-dimensional gold nanoparticle array merged in a water matrix, they demonstrated that high-frequency phonon excitations could be tuned via the manipulation of the nanoparticle superlattice structure.[24]

Proposed Research: In the remaining 6 months-extension of the LDRD, the group aims at using IXS techniques to explore a new science frontier: the characterization of phonon propagation in nanoparticle assemblies, liquid crystals, block copolymers and phononic crystals. These studies will elucidate fundamental aspects of sound propagation in complex soft matter systems, which are responsible for heat propagation at molecular scales, thus lending themselves to innovative applications for energy and heat management at nanoscales.

Supported by BNL LDRD-15-031

DOORYHEE, ERIC

Research Accomplished: Dooryhee and co-workers used Modulation Enhanced Diffraction (MED) as a new tool for powder diffraction and total scattering studies. This project was crucial for benchmarking MED that has the potential to be applicable to industry-relevant questions, such as adsorption/desorption in membranes and filters, reversible ion intercalation in host matrices for batteries and fuel cells, or change of surface states in automotive catalysts under changing pressures of the reactants. MED was validated on colloidal tungsten oxide nanocrystals (WO_{3-x}), as a model polymorphic nanoscale material system.[32]

Supported by BNL LDRD-13-031.

DVORAK, JOSEPH

Research Accomplishments: Dvorak's general area of research and development is in the optical design of state of the art soft X-ray beamlines for NSLS-II. Dvorak's first research accomplishment is oversight of the design of the SIX spectrometer, and the metrology and installation of the optics on the SIX beamline and spectrometer.[10] Gratings are crucial to the operation of soft X-ray beamlines, and currently are the limiting optics in terms of resolution and throughput. In collaboration with the NSLS-II metrology group and the metrology group at APS,

Dvorak and coworkers are developing the metrology tools required to fully characterize diffraction gratings for two reasons: first, so that their optical performance can be determined prior to installation in a beamline, and second, to provide feedback to the ruling process to allow the production of higher quality gratings. These efforts have led to first order Littrow measurements of the line density and interferometric microscope measurement of line placement errors at BNL, and the development of a high-intensity Long Trace Profiler at the APS for the measurement of low blaze angle gratings.

Supported by NEXT Project

EHM, LARS

Research Accomplishments: Ehm and co-workers: 1) developed new methods to measure the atomic structure of amorphous and nanocrystalline materials at high pressure and applied these to investigate the compression behavior of germania glasses and platinum and gold nanoparticles as a function of particle size[33-38] and 2) proposed a mechanism for the pressure induced amorphization transition in feldspars, a widely used shock pressure indicator, based on X-ray total scattering data and infrared spectroscopy measurements.[39]

Proposed Research: Future research will mainly focus on the investigation of Earth and other materials under "fast" compression and heating conditions. Ehm's recent work has shown that variation of the compression and heating rate allows access to a vast region in the p-V-T space that remains inaccessible with static or shock compression techniques. Bridging this gap has a high potential to reach states and forms of materials that are far from the thermodynamic equilibrium, and potentially have novel and desirable properties.

Supported by NSF-GEO and NSF-EAR (COMPRES)

EVANS-LUTTERODT, KENNETH

Research Accomplishments: 1) Evans-Lutterodt and co-workers used an X-ray micro-beam to study the structure of human hair. The X-ray beam was sub-micron in one direction, and by proper sample preparation and orientation in the X-ray beam, they were able for the first time to obtain diffraction that came separately from each of the three major regions of human hair, cuticle, cortex and medulla. While it is well known that the primary constituent of human hair is alpha-Keratin, they discovered that the cuticle of hair contains beta-keratin. The cuticle is the thin layered structure that encloses hair, and beta-keratin has a layer-like crystal structure, so even though this had not been previously known or suggested, it is easily understood.[40] 2) A diamond kinoform lens was fabricated and tested, providing a sub-micron focused spot. 3) A set of silicon kinoform lenses was designed and fabricated for the CHX beamline, and essentially all data generated by users at the CHX beamline have used the kinofom lenses. 4) High energy focusing lenses have been tested, with photon energies as high as 107 keV.*

Proposed Research: 1) With the funded project on optics for high energy focusing, Evans-Lutterodt proposes to deliver lenses that can create 100nm sized beams with 100 keV photons, with applications that include Diamond Anvil Cell experiments at high pressures. 2) Using the polarization capabilities of the ISR beamline he proposes to bring focusing optics to allow the study of magnetic materials with spatially resolved magnetic X-ray diffraction.

*Supported by NEXT Project and * by the DOE Accelerator and Detector Research Program*

FUCHS, MARTIN

Research Accomplishments: Within the ABBIX beamline construction project Fuchs continued with the design and construction of instrumentation for the macromolecular crystallography beamlines FMX and AMX. He led and completed the project for the development of the experimental stations.[41] Since 2015, Fuchs is Lead Beamline Scientist for the FMX beamline. As covered by this LDRD proposal, a high-precision, high-speed piezo scanner goniometer is being developed, currently in commissioning at the beamline. Within the LDRD, a postdoc is designing and fabricating micro-structured Si sample supports for scanning serial crystallography at the BNL Center for Functional Nanomaterials. These advances are reported in a review article.[42]

Proposed Research: The goal for the remainder of 2017 is to deliver the full and robust performance of the FMX photon delivery system and experimental stations. Automation of sample mounting and beam delivery will further be developed to support and advance the FMX User Program. Beginning in 2018, the beamline structural biology program will be developed with a focus on fully researching, establishing, and exploiting the advantages of the FMX micro-beam. The Serial Microfocus Crystallography LDRD program will conclude with the integration of the scanner in the FMX experimental station, and first experiments demonstrating its full flux performance and scientific opportunities.

Supported by NIH and BNL LDRD

GHOSE, SANJIT

Research Accomplished: Ghose has worked as co-PI on two BNL LDRDs to develop and accomplish two scientific projects. 1) Modulation Enhanced Diffraction (MED) as a new tool for powder diffraction and total scattering studies. This project was crucial for benchmarking MED that has the potential to be applicable to industrially-relevant questions, such as adsorption/desorption in membranes and filters, reversible ion intercalation in host matrices for batteries and fuel cells, and the change of surface states in automotive catalysts under changing pressures of the reactants. 2) A new system of slits, known as 'spiderweb slits,' have been developed for depth resolved powder or polycrystalline X-ray diffraction measurements. The slits act on diffracted X-rays to select a particular gauge volume of sample, while absorbing diffracted X-rays from outside of this volume. Depth-resolving techniques are especially important for in situ experiments that may present unwanted diffraction or scattering sources, such as battery cell containers, reaction cell or pressure cell windows, or for complicated composite structures.[43] A patent was filed for this work.

Supported by BNL LDRD-13-031

GRAZIANO, VITO

Research Accomplishments: Graziano and co-workers: 1) installed an in-line size exclusion chromatography (SEC) system for unattended high-throughput sample processing at the LIX beamline; 2) used SEC coupled to SAXS/WAXS to study the conformational changes of a calcium channel membrane protein as a function of pH; 3) used SEC-SAXS to measure the size

of polymer bounded nanodiscs, observing that by varying the styrene maleic acid-to-lipid ratio one can control the size of the resulting nanodisc; and 4) using various biochemical methods, developed experimental protocols to embed membrane proteins in SMA-nanodiscs.

Proposed Research: Future research will focus on extracting structural information from SAXS/WAXS data for membrane proteins embedded in SMA-nanodiscs. New *ab initio* 3D shape reconstruction algorithms will be developed to account for the different electron density regions in the lipid bilayer.

Supported by NIH

HUANG, XIAOJING

Research Accomplishments: *new project*

Proposed Research: Dr. Huang will develop a novel nano-scale 3D imaging technique combining the high-resolution capability of ptychography with the depth distinguishing power of a multi-slice method. This project will eliminate the requirement of sample rotation and target the inherent challenges in existing 3D microscope systems that prevent one achieving high resolution from thick specimen and obtaining 3D structural information from samples under in-situ environments.

Supported by BNL LDRD-16-007

IDIR, MOURAD

Research Accomplishments: *new project*

Proposed Research: Idir proposes to complete the development of ion-directed reactive-etching profiling for fabrication of X-ray mirrors capable of diffraction-limited focusing and wavefront preservation. This capability is essential to realize the potential of ultra-high brilliance sources like the NSLS-II and will foster the development of the next generation of advanced synchrotron instrumentation and science. The project goals are firmly based on our experience and prior collaboration with CFN and provide a good use of unique equipment developed at the NSLS-II R&D labs. The original concept and patent implications have been confirmed by the BNL Technology Transfer Office. Key milestones are: 1) design a state-of-the-art Ion Beam Figuring platform with the goal to produce high quality curved x-ray mirrors, 2) test software, data acquisition and online analysis, 3) implement and develop a state of the art Ion Beam Figuring platform, and 4) achieve first test of a dedicated KB system.

Supported by BNL LDRD-17-016

JAKONCIC, JEAN

Research Accomplishments: Jakoncic was focused on the design and construction of instrumentation for the macromolecular crystallography beamlines FMX and AMX and the scattering beamline LIX. He developed the in-house automated sample delivery system using a six axis robotic arm fitted to specialized gripper to achieve a very high throughput. He

implemented a High Performance Computing solution to deal with the unprecedented data volumes and developed a set of prototype automated data processing and structure solution pipelines, including some initial scripts for many crystals data collection. In addition, Jakoncic and co-workers advanced the following projects: 1) structural studies of L,D-transpeptidase from *Mycobacterium tuberculosis revealing its importance in maintaining the cell wall integrity in M. tuberculosis*[44]*; 2)* crystallographic structures of SdsA, a sodium dodecyl sulfate hydrolase from *Pseudomonas aeruginosa from various crystal polymorphs*[45]; 3) studies on the influence of chirality in protein crystallization: crystallization of lysozyme with R-, S-, and RS-MPD[46]; 4) structural studies of CBX7 chromodomain with various small molecules modulating binding of methyl-lysone: potential candidate to be developed as modulator targeting CBX7 functions[47]; 5) structural characterization of repressor of toxin (Rot) a central regulator of *Staphylococcus aureus,* responsible for a large number of infections worldwide: insights into better understanding how Rot controls virulence factor regulation[48]; 6) crystallographic studies of the voltage gated sodium channels (NaV) shedding light to the physiological activation and the pathophysiology of Na(v) channels[49]; and lastly, 7) crystal structure of replication protein A subunit RPA32 bound to the N-terminus of the DNA damage protein response SMARCAL1 redefining the common recognition pattern shared by RPA32C interacting proteins[50].

Proposed Research: Research will focus on four areas: 1) automated and advanced sample delivery for macromolecular crystallography with high capacity/density applications; 2)

develop methods to solve structures from many crystals; 3) enable near real time data processing using optimized algorithms in an HPC environment; 4) data collection at low x-ray energies with He environment to solve structure of challenging protein crystals and at very high energy to minimize radiation induced damages; 5) structural studies of biological samples.

Supported by NIH and DOE-BER

JARRIGE, IGNACE

Research Accomplishments: Jarrige has led the construction of the soft inelastic X-ray scattering (SIX) beamline and spectrometer at NSLS-II, and the development of its science capabilities. Jarrige also conducted research as principal investigator using high-resolution RIXS on high-Tc superconductors, Kondo compounds including topological Kondo insulators, and automotive catalysts. The work on high-Tc superconductors revealed new details on the low-energy charge and spin excitations in iron-based superconductors.[51] A study on the Kondo compound uncovered a link between the electronic spectrum of this material and the amplitude of its Kondo effect, which can have implications for magnetocaloric technologies.[52] Lastly, an investigation on intelligent automotive catalysts pointed to an intimate connection between their high catalytic efficiency and their peculiar electronic structure. This finding can serve as a guide to optimize the efficiency of intelligent catalysts by manipulating their electronic structure.[53]

Supported by NEXT Project

KEISTER, JEFF

Research Accomplishments: Since 2013, Keister has been assigned as Deputy Project Manager for the NEXT Project, delivering five world-class beamlines to NSLS-II by end of FY17. In parallel with these efforts, independent research has progressed in the following areas: 1) development of luminescent diamond screens for synchrotron white beam imaging[54]; 2) absolute responsivity and optical performance characterization of ultra-pure, single-crystal diamond for x-ray photocurrent sensing (data collected at BESSY-II in 2016); 3) implementation of assembly and X-ray flux measurement capability using silicon photodiode sensor enclosure; and 4) developed a method for detection of microcalcifications by X-ray imaging with a conical slit.

Supported by the NEXT Project

LAZO, EDWIN

Research Accomplishments: Lazo collaborated with the Ojima lab from Stony Brook University which has resulted in the determination of a crystal structure of *Mycobacterium Tuberculosis* Filamenting temperature-sensitive mutant Z (MtbFtsZ) that has revealed a novel interaction (PDB entry 5v68).

Proposed Research: To complete the deployment of the AMX robotics system and to support both systems by the addition of features, optimization, and maintenance. To be involved in the development and testing of the robotic system that will be implemented at the solution scattering beamline, LiX. In addition to the automation projects, Lazo will continue his collaboration with the Ojima lab to examine the interactions of novel drugs they developed with MtbFtsZ.

Supported by the NIH

LEE, WAH-KEAT

Research Accomplishments: In collaboration with another LDRD (Stuart Wilkins PI), and a few members of the Controls group, a novel, modular and flexible data acquisition, management and analysis architecture and platform was developed and deployed at NSLS-II. This development is driven by the requirements of the facility, which is in turn, is driven by the high brilliance and X-ray flux of the NSLS-II and by new technological advances such as very high frame rate area detectors. Key features of this new platform are: distributed storage, each optimized to its immediate function; modular approach, for example, the data acquisition module is separate from the data access module; independence of hardware/hardware drivers or choice of database; and independence of output data format, data is stored in optimized native format and can be accessed and packaged to specific formats as required by users.

Supported by BNL LDRD-13-033

LIU, QUN

Research Accomplishments: Liu joined the Biology Department in September 2015 with a joint appointment at NSLS-II. He had been previously working at NSLS beamlines X4; there he developed the multi-crystal *ab initio* anomalous phasing technology. Based on his work at NSLS and NSLS-II, he developed and optimized native-SAD phasing method for low energy and low resolution applications.[55-58] He also determined the structures and activities of a bacterial TMBIM calcium channel[59], solved crystal structures of a bacterial bestrophin channel[60] and a tryptophan-rich TSPO protein[61]. In addition, he participated in the immune complex involved in thrombocytopenia.[62] On dissemination of his research accomplishment, Qun Liu has been invited to write review articles on crystallographic phasing technology[63] and scientific findings on TMBIM channels[64].

Proposed Research: Liu and co-workers propose to work on: 1) mechanisms of biological conversion of hydrocarbons for bioproduct production (BNL LDRD); 2) structures and mechanisms of membrane proteins in defining beneficial traits for biofuel and bioproduct production in bioenergy crops (DOE-BER); 3) continuation of the technical development in serial and time-resolving microcrystallography (including sample preparation, presentation, and data analysis) at NSLS-II beamlines FMX, AMX, and NYX (BNL LDRD, Columbia NIH subcontract); 4) technical development to encage biological molecules for structural analysis by synchrotron x-ray scattering (LIX beamline) and cryo-electron microscopy at Biology Department and CFN

Supported by DOE-BER, Columbia NIH subcontract, DOE-ASCR, and BNL LDRD-17-023

MCSWEENEY, SEAN

Research Accomplishments: Two threads have been followed: firstly the close out of work started with collaborators at the ESRF Grenoble, France. This activity has led publications describing the instrumentation built and beamlines constructed[65-67]; some of these ideas are being transferred into the instruments available at NSLS-II. The second strand of work is the reporting of structural biology work contained in particular work on the extremophile *D. radiodurans* where results were reported on the DNA repair mechanisms of the organism and the composition of the bacterium's cell membrane[68-70]. Efforts at using the NSLS-II have involved the development of new methods to use the opportunities that the source presents, data analysis and massively serial data collection being part of the mix[41,71-74]. This work has been supported through LDRD funding starting in 2014 enabling us to explore the statistical means to piece together fragmented data sets, and through collaborations within the DOE complex and with colleagues at other light sources. Further structural biology work has been undertaken in collaboration with the Biology department at BNL leading to the establishment of the Quantitative Plant Science initiative (QPSI), where a substantial strand of the research concerns the impact of structural biology on understanding, modeling and predicting behavior of plant genotypes.

Proposed Research: exploiting the potential of the NSLS-II for structural biology will take a number of interwoven paths: development of an understanding and mitigation strategies for the radiation damage induced upon exposure of bio-molecules to the x-ray beam; continued statistical

analysis of the fragmented, weak, diffraction patterns obtained, and the use of these data for structure elucidation. We will continue to collaborate with BNL Biology through QPSI and other schemes to further our approach and in particular leverage the successful application to the Joint Genome Institute for genetic and structural investigation into the "Green Cut" – those genes common to all photosynthetic organisms.

Supported by NIH, DOE-BER, and BNL-LDRD

MILLER, LISA

Research Accomplishments: Miller and co-workers advanced the following projects: 1) They identified structural changes in collagen and mineral nanostructure in osteoporosis and pharmaceutical treatments using simultaneous small- and wide-angle X-ray scattering.[75] 2) They developed a new method for examining protein structural changes in living cells using full-field synchrotron infrared imaging. This technique was applied to understand protein misfolding in genetic variants of amyotrophic lateral sclerosis (ALS).[76] 3) They used synchrotron infrared microspectroscopy and confocal microscopy to identify the secondary structure of opsin mutants in retinitis pigmentosa. This work was feature on the cover of FEBS Letters.[77] 4) In two different synchrotron infrared microspectroscopy studies, they examined how bone matrix and mineral content are affected by parathyroid hormone treatment[78] and a mutant strain bred for high bone mass[79].

Proposed Research: The Miller group is interested in the role of metal ions in neurodegeneration in protein folding diseases. In the past year, two new NIH grants were funded to look at protein misfolding in cerebral amyloid angiopathy (CAA) and retinitis pigmentosa (RP), respectively. In the first project, a mouse model of CAA will be examine function of dietary copper content. In the second project, mouse models of RP containing variants of the opsin protein will be examined. In a third project, efforts to develop protein-fusion tags for X-ray fluorescence Microscopy (XFM) are underway. XFM is becoming a widespread method for imaging trace element concentration, distribution, and speciation in biological cells at the nanoscale. However, one limitation of XFM for imaging biological systems is detecting trace-element distribution in the context of subcellular organelles and individual proteins. For visible light microscopy, the most ubiquitous method for imaging individual proteins within the context of a living cell is the use of fluorescent proteins such as GFP or YFP that are co-expressed as a fusion tag along with the protein of interest. However, visualization of these tags is limited by the wavelengths of visible light. We are currently developing applications enabled by lanthanide-binding tags (LBTs), which are GFP-like analogs of minimal size for XFM. The LBTs are enabling better than 10 nm resolution imaging of individual proteins in cells while simultaneously obtaining trace element distribution throughout the cell.

Supported by NIH and DOE-BER

NAZARETSKI, EVGENY

Research Accomplishments: An alternative approach to X-ray nano-imaging has been explored; dedicated carbon nanotube based tips for X-ray assisted scanning tunneling microscopy experiments have been developed [DOI: 10.1155/2015/492657] and tested on APS beamlines.

Supported by BNL LDRD-13-034

Proposed Research: 2D Multilayer Laue Lenses nanofocusing optics has a potential to complement conventional zone plates in the hard X-ray regime, yielding efficiency and higher spatial resolution. They also hold a potential to be implemented in full-field imaging systems. We propose to use microfabrication processes to develop dedicated templates to support and align individual 1D optics enabling point focusing. Developed devices will be designed, fabricated and tested with a goal of being implemented into X-ray microscopes at NSLS-II and elsewhere.

Supported by BNL LDRD-17-017

NELSON, CHRISTIE

Research Accomplishments: Nelson and co-workers advanced the following projects: 1) They used heat capacity, pressure-dependent X-ray diffraction, magnetic field-dependent local probe measurements, and density functional theory calculations to investigate magnetostructural correlations in $HoAl_3(BO_3)_4$. Although no distortions of HoO_6 polyhedra are observed, correlations between neighboring polyhedra are enhanced in a magnetic field and saturate, due to the stiffness of the lattice, in the region of large magnetoelectricity exhibited by this material.[80] 2) They solved the magnetic structure of Yb_2Pt_2Pb using complementary neutron and X-ray scattering techniques. The frustrated magnetic interactions in this Shastry-Sutherland lattice system result in a complex ordering of the in-plane, Ising-like Yb moments below $T_N = 2.07$ K, with independent sublattices that are separately polarized in magnetic fields applied in orthogonal directions.[81]

Supported by NEXT Project

RUMAIZ, ABDUL K.

Research Accomplishments: Rumaiz and co-workers advanced the following projects: 1) They developed germanium detectors for high-energy applications primarily for use at the XPD beamline. Initial work on a 64 element germanium strip and a proof of energy dispersive diffraction experiment was published as a paper.[82] They are building a 384 germanium strip which will be used at the XPD beamline at NSLS-II and at the APS. Currently the 64 strip germanium with modified MAIA detector read-out is installed 6-BM at the APS for a program of energy-dispersive diffraction. That installation is just beginning to produce new science.* 2) VIPIC is a detector custom-designed for x-ray photon correlation spectroscopy (XPCS). With its sparsified read-out scheme VIPIC is the fastest available detector. Furthermore, VIPIC was the first demonstration for 3D technology where different components are bonded in 3D using through silicon vias. The first prototype was tested for a XPCS measurement[83] and relaxation times into sub milliseconds were measured.* 3) The Maia system continues to be made available via our partner, CSIRO; changes in the sensor fabrication procedure have resulted in a significant reduction in leakage current. Eventually, with lower leakage current the device could potentially work in room temperature without the need of peltier cooling.**

Proposed Research: Rumaiz and co-workers are engaged in an effort to build a 1 Megapixel version of VIPIC detectors. This would be used at NSLS II and at APS. Moving forward the

detector group would like to develop in-house process for bump-bonding and direct oxide bonding technology used in 3D processing..

** Supported by DOE Accelerator and Detector R&D Program*

*** Supported by WFO Contract with CSIRO*

SCHNEIDER, DIETER

Proposed Research: Development of the AMX beamline's capabilities and advanced experimental methods will continue with emphasis on providing rapid and reliable adaptations of experimental parameters to facilitate optimal data collections and structure determinations. Through collaboration with one or a few leading structural biologists, a flagship project will be identified that takes full advantage of the unique opportunities that AMX affords: automation-assisted data collections at unprecedented flux densities.

Supported by the NIH

SIDDONS, D. PETER

Research Accomplishments:

1) A germanium microstrip detector is installed at the APS 6-BM for a program of energy-dispersive diffraction, which is just beginning to produce new science.* 2) VIPIC is a detector custom-designed for X-ray photon correlation spectroscopy.[83] Following our successful demonstration of its technology, a new project to build a 1M pixel version has proceeded steadily, with no major roadblocks.* 3) The Maia system continues to be made available via our partner, CSIRO. One or two systems per year have been produced.**

Proposed Research: 1) The Maia system energy resolution is limited to around 250 eV at 6 keV. The state of the art for a single detector is significantly lower than this. The focus of the group is on improving this aspect of the system. A new ASIC has been produced which has lower noise than the existing system, but it needs a low-capacitance sensor to take advantage of its performance. An array of silicon drift detectors (SDDs) has been designed and a first attempt been made to fabricate it. The new device will have 384 SDDs, in a physical format which mimics the Maia. This is the largest array of SDDs ever proposed or realized, and is a challenging fabrication task. The first devices were functional, but suffered from a high leakage current which spoiled the energy resolution. A new batch is being fabricated with some modifications to help reduce leakage. 2) Development of a spectroscopic imaging detector (HEXID) continues. In conjunction with this development, an optical system is being designed which will allow achromatic full-field imaging of an X-ray-fluorescing sample.

** Supported by DOE Accelerator and Detector R&D Program*

*** Supported by WFO Contract with CSIRO*

SOARES, ALEXEI

Research Accomplishments: The large increase in X-ray brightness at NSLS II allows novel macro-molecular crystallography (MX) applications such as serial crystallography and combinatorial crystallography. To exploit these opportunities, Soares has developed novel acoustic droplet ejection (ADE) techniques that use sound waves to move protein crystals and/or to combine protein crystals with chemical cocktails. ADE applications use sound waves to manipulate protein crystals and chemical building blocks on a much faster time scale and on a much smaller size scale than is possible with any other technique. ADE can be used to miniaturize and accelerate many different kinds of science, but the principle applications at BNL have been to inject protein crystals into X-ray beams (acoustic serial crystallography) and to combine chemical libraries with protein crystals (acoustic combinatorial crystallography):

Acoustic serial crystallography Soares and co-workers developed techniques that have been deployed at the new LCLS beamline MFX.[1,2,84] Storage ring applications at NSLS II are being developed now.

Acoustic combinatorial crystallography techniques are currently available to NSLS-II users.[72,85-88] Continued improvement will make these techniques easier and more powerful. The first user specimen at AMX was prepared using ADE (leading to a novel structure for the laboratory of Dr. Page), but the process was too complex for the user to accomplish without support, so further improvements are still needed.

Proposed Research: Applications of ADE to crystallography have largely been demonstrated. Future research will focus on deploying these techniques in support of beamline operation at AMX and FMX. Acoustic combinatorial crystallography operations in the specimen preparation facility must be simplified (so that users can carry out experiments in person) and must be integrated with the automation program at AMX (for rapid screening of cryo-preserved crystals) and with the plate handling facility at FMX (for obtaining *in situ* diffraction from crystals inside of crystallization plates). Acoustic serial crystallography may be deployed at FMX also, but this will require improvements to computation capabilities to handle the very large streams of data. There is also the potential to demonstrate acoustic applications in support of BNL Biology department missions such as cell harvesting (current collaboration with Dr. Ian Blaby) or the effort to launch a Cryo Electron Microscopy user service (current collaboration with Dr. Qun Liu).

Supported by NIH and DOE-BER

STAVITSKI, ELI

Research Accomplishments: Stavitski's research is centered on applications of synchrotron X-ray absorption and scattering methods to heterogeneous catalysts and advanced nanoporous materials, with the aim of understanding physicochemical processes behind these materials activity and selectivity. Stavitski and coworkers: 1) demonstrated applications of novel microreactor for multi-technique operando characterization of heterogeneous catalysts[89] and 2) using X-ray spectroscopy and diffraction, unraveled the origin on nickel aluminate perovskites in dry methane reforming[90].

Continuing his work on the applications of synchrotron infrared micro-spectroscopy, Stavitski and co-workers reported on the performance of a novel infrared beam stabilization scheme[91] and the development of an in-situ environmental cell to follow protein structural changes in living cells using time-lapsed infrared imaging[76]. Over the last year, his activities concentrated on the design of the Inner Shell Spectroscopy beamline, a hard X-ray spectroscopy beamline at NSLS-II. Stavitski and coworkers developed an encoder interface for NSLS-II beamline motion scanning applications[92] and a polycapillary X-ray optics for synchrotron spectroscopy[93].

Supported by NEXT Project.

STOJANOFF, VIVIAN

Research Accomplishments: Stojanoff continues to study different crystallization methods. Specifically, she is interested on the effect of electromagnetic fields on the quality of protein crystals. Stojanoff and co-workers: 1) published a review on the current status of the effect of electric fields on the crystallization of macromolecular crystals[94], 2) demonstrated the use of Si crystal matrixes as nucleation centers for macromolecular crystals[95], 3) completed the structure determination of several macromolecules and modulation of gel phase model membranes by vitamin D.[45,47,96,97]

Proposed Research: encompasses three subject areas: 1) development and implementation of crystallization methods and crystal quality assessment; 2) implementation of X-ray methods in protein crystallography; 3) exploration of complementary methods to solve specific problems in structural biology. To pursue these objectives Stojanoff proposes to further continue the study on the effects of electromagnetic fields on crystallization and the crystallization of uniformly sized macro- micro- nano- crystals. Stojanoff will continue to explore X-ray methods applied to structural biology. She is further engaged in the pursuit of methods such as scattering methods (SAXS and scanning micro imaging) and the continued application of high energy X-rays in structural biology. Stojanoff proposes to apply complementary methods such as electron microscopy within the LSBR mission in structural biology.

Supported by NIH-NIGMS and DOE-BER

THIEME, JUERGEN

Research Accomplishments: Thieme is co-investigator in the Solar System Exploration Virtual Institute (SSERVI) "Remote In-Situ and Synchrotron Studies for Science and Exploration (RIS4E)" funded by NASA and lead by Stony Brook University. He is working on in-situ measurements of space weathering of minerals using a high-power laser at the beamline.

Supported by NASA

VESCOVO, ELIO

Research Accomplishments: Vescovo was beamline leader in the design and construction of a new photoemission beamline at NSLS-II, the ESM beamline. Two main projects reached fruitful results during this period. The first project involved the study of the fcc/bcc phase separation in FeNi alloys. FeNi alloys undergo a bcc to fcc transition as a function of Fe content. In bulk

specimens the transition is very slow and is usually observed in macroscopic quantities only in samples collected from meteorites with a natural treatment at high temperatures and astronomical times. In epitaxial ultrathin films the transition is instead mediated by surface diffusion of vacancies and can be directly monitored with XPEEM in matter of minutes and at much lower temperatures. The study by Vescovo and co-workers identified the driving process in the phase separation by quantitatively assessing the energy barrier of the Ni diffusion process[98]. The second project is based on an artificially engineered metallic multilayer which combines a strong ferromagnet (Fe) to a Rashba system (Ag_2Bi). Spin-orbit and exchange interactions are therefore both present in the same system and their interplay can be readily monitored by measuring the energy bands. The result is the formation of a novel electronic structure featuring asymmetric gaps in the Rashba system induced by the ferromagnet. The asymmetry can be moved in the reciprocal space in a binary way by rotating the magnetization[99]. Both studies involve the physics of ultrathin films and their extraordinary properties with no equivalent in the bulk materials.

Supported by NEXT Project

WALTER, ANDREW

Research Accomplishments: Walter and co-workers investigated the electronic structure of novel 2D systems such as graphene, 2D metallic alloys and organic molecular films. In particular focusing on substrate induced effects. This will have a significant impact on their technological use as they will, by necessity, be employed on substrates. 2) They advanced studies of chemical functionalization of graphene, which introduces important technological properties such as luminescence, and photon derived patterning of semi-conducting and metallic regions. 3) They pursued studies of electronic variations in surface layers and overlaid films derived from surface structural changes, predominantly through the use of novel "curved" crystals which provide a unique opportunity to systematically vary the terrace density on miscut surfaces.[100-103]

Proposed Research: 1) Continue examination of systems exhibiting new and novel electronic structures, with an emphasis on 2D materials and their derivatives. 2) Continue investigations utilizing systematic structural variations to affect electronic changes in novel materials. 3) Begin investigations into micro-structured materials, with the aim of utilizing the small spot and high energy resolution of the new ESM beamline.

Supported by the NEXT Project, ESF (European Science Foundation), DFG (German Research Foundation), Max Planck Society, DIPC (Donostia International Physics Centre), CFM-CSIC (Spanish Science Foundation).

YAN, HANFEI

Research Accomplishments: Yan and co-workers studied the dynamical diffraction effects in Bragg coherent diffractive imaging from both theoretical and experimental perspectives.

Proposed Research: Mapping the strain in 3D and on nm length scale is critical to understand physical properties of many functional materials. X-rays have excellent detection sensitivity for strain measurement and their penetration power allows for nondestructive study. Conventional X-ray methods, however, only provides an "average" strain value over the illumination volume,

lacking the capability of nanoscale strain imaging in 3D. We propose to combine the scanning nanoprobe and Bragg diffraction with phase-retrieval techniques to tackle this challenge.

Supported by BNL LDRD-14-021

YANG, LIN

Research Accomplishments: Yang led the construction of the LiX beamline[26], including the in-house development of several components and the specialized endstation instrumentation dedicated to the measurements of X-ray scattering from biological samples. A major accomplishment is a solution scattering experimental module with an integrated in-line size exclusion chromatography system, and with EPICS-based controls utilizing a single-board computer. In addition, Yang and collaborators analyzed X-ray scattering data from hydrophobic amino acids in solution as a way to verify the force fields used in simulations of processes such as folding.[104]

Proposed Research: Continue to develop instrumentation and data analysis methods for structural biology research at LiX. Specifically, Yang will work on anomalous scattering at tender x-ray energies, scattering from complex structures such as lipid nanodiscs, and imaging of biological tissues using x-ray scattering as a contrast mechanism.

Supported by NIH and DOE-BER

ZHERNENKOV, MIKHAIL

Research Accomplishments: Zhernenkov and co-workers advanced the following projects: 1) They used a PNIPAM polymer surface coating atop a nanostructured linear diffraction grating to controllably change the surface topography of 2D linear structures using temperature stimuli. This system demonstrated advanced performance in the effective alignment of cultured fibroblast cells and the easy release of the cells upon temperature change.[105] 2) They used inelastic X-ray scattering (IXS) experiments combined with the molecular dynamics (MD) simulations on deeply supercritical Ar to unveil the mechanism and regimes of sound propagation in the liquid matter and provided compelling evidence for the adiabatic-to-isothermal longitudinal sound propagation transition.[20] * 3) They continued IXS and MD study of supercritical Ar and observed that, upon temperature increases, a low-frequency transverse phononic gap emerges while high-frequency propagating modes become evanescent at the THz scale. The effect of strong localization of a longitudinal phononic mode in the supercritical phase is observed for the first time.[22] * 4) For the first time, they experimentally observed a thermodynamic boundary – The Frenkel Line – on the pressure-temperature diagram in a deeply supercritical sample through diffraction measurements in a diamond anvil cell. The existence of the structural crossovers was given in the framework of the phonon theory of liquids and using molecular dynamics simulations.[21] *5) They introduced a unified approach to states of matter (solid, liquid and gas) and described the thermodynamics of the pressure–temperature phase diagram in terms of phonon excitations.[23] 6) They found evidence for propagating in-plane transverse phonon modes in a DPPC lipid membrane. These transverse phonon modes exhibit phononic gaps upon temperature increase, providing a direct signature of the existence of transient voids caused by short-lived lipid density fluctuations that mediate solute permeation across the membrane.[106] 7) They studied terahertz phononic excitations in two-dimensional (2D) gold nanoparticle arrays in a water matrix through a series of large-scale

molecular dynamics simulations and observed acoustic Dirac-like crossings in H (H_2O) atomic (molecular) networks that emerge due to an intraband phononic scattering.[24] * 8) Lastly, they showed that the integral hard-X-ray-induced photoemission yield is modulated by the Fresnel reflectivity of a multilayer structure and carries structural information that extends well beyond the photoelectron escape depth.[107]

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1.viii External Input to the Facility

Below we will describe the external input to the facility (scientific advisory committee, user organization committee, etc.) and the frequency of this input.

A key aspect of the NSLS-II strategy in operations is a close engagement with the scientific community and with key stakeholders in the form of external input to the facility and cooperative partnerships for the development and operations of NSLS-II beamlines, facilities and associated science programs. Following this strategy, NSLS-II has established a number of processes and standing advisory committees, listed below, that allow external communities to provide advice and recommendations on a variety of topics relevant to NSLS-II facility development and operations as well as to its scientific productivity.

In addition to these standing committees, NSLS-II often convenes external peer review panels as needed. Recent examples include external peer reviews of the NSLS-II beamline projects. Websites for most of these project reviews are available at http://www.bnl.gov/nsls2/project/ review Docs. NSLS-II also institutes periodic peer reviews of specific operating programs, such as the X-ray optics and detectors R&D, the Data Acquisition/Management/Analysis, and NSLS-II beamlines, the latter of which are typically held every three years, or sooner on an as-needed basis.

Each advisory committee and external peer review provides an essential opportunity for internal critique, healthy discussion of important issues and concerns, and advice and recommendations for critical decisions that will impact the scientific programs and communities. The committees complete written reports documenting their findings, comments, and recommendations. The recommendations are tracked to closure and responded to as part of our overall management process.

Science Advisory Committee: NSLS-II Science Advisory Committee (SAC) is responsible for providing advice on issues related to the scientific utilization of NSLS-II and on developments required to achieve and maintain the highest possible scientific productivity. In keeping with this, the SAC provides advice on the following topics:

- Scientific output and utilization of NSLS-II facility
- Long-term scientific directions
- Planning, development, and operation of NSLS-II facility
- Policies and procedures relevant to user access and utilization of scientific facilities

The SAC also carries out reviews of operating beamlines, makes recommendations on proposed beamlines and partnerships and provides input on the NSLS-II strategic plan.

The SAC is chaired by Harald Reichert, ESRF, and has an outstanding membership of 12 individuals chosen to represent a diversity of opinions from national/international, academic /national lab/industry, and different areas of science and techniques. In addition, the NSLS-II UEC Chair serves as an Ex-Officio member of the SAC. The full membership (names and affiliations) of the NSLS-II SAC is posted at https://www.bnl.gov/nsls2/committees/ and listed below:

- Harald Reichert, Chair, (European Synchrotron Radiation Facility)
- Jingguang Chen (Columbia)
- Bruce Gates (Univ. California)
- John Hemminger (Univ. California at Irvine)
- Franz Hennies (MaxLab)
- Robert Hettel (SLAC)
- Steve Kevan (Univ. Oregon)
- Eugene Lavely (BAE Systems)
- Ingrid Pickering (U. Saskatchewan)
- Harald Reichert (ESRF)
- Janet Smith (Univ. Michigan)
- Soichi Wakatsuki (SLAC)
- Jen Bohon (Ex-Officio/CWRU/UEC Chair).

The SAC meets twice per year, typically in the spring and fall of each year. The link to the SAC Website can be found here: https://www.bnl.gov/nsls2/committees/ .

***NSLS-II Proposal Review Panels*:** The NSLS-II Proposal Review Panels (PRPs) are responsible for reviewing and rating new general user / partner user /science commissioning proposals based on their scientific merits, technical innovation, experimental plans, and quality of the experimenters. The rank order of scores generated by the PRPs is the primary input in the allocations of General User or Partner User beam time. The PRPs provide feedback to the investigators on the quality of their proposals and, where relevant, on perceived weaknesses.

The NSLS-II Proposal Review Panels each focus on a specific research area. Each panel is composed of a number of scientific peers from outside NSLS-II. These experts are chosen to provide a range of expertise and experience in the specific field of research, including in the industrial, instrumentation, and method development representation as appropriate. One member of each panel is appointed by NSLS-II as the Panel Chair. The membership for each panel may change from run-cycle to run-cycle depending on the number of proposals received in a given field. The current NSLS-II PRP memberships can be found at https://www.bnl.gov /ps/docs/pdf/PRP-Members.pdf

The NSLS-II PRPs meet three times a year at BNL to review submitted proposals. In some cases such meeting may be conducted remotely through Skype or BlueGene.

As of April 2017, the NSLS-II PRP consists of the following panels and membership:

Soft X-ray & Photoelectrons:
Riccardo Comin (University of Toronto)
Ian McNulty, Chair (Argonne National Laboratory)
Eli Rotenberg (Lawrence Berkeley National Laboratory)
Andreas Scholl (Lawrence Berkeley National Laboratory)

X-ray Spectroscopy
Simon Bare (SLAC National Accelerator Laboratory)
Shelly Kelly (UOP LLC)
John Newberg (University of Delaware)
Hiro Ogasawara (SLAC National Accelerator Laboratory)
Bruce Ravel, Chair (National Institute of Standards and Technology)
Ashaki Rouff (Rutgers University)
Trevor Tyson (New Jersey Institute of Technology
X-ray Scattering:
Brian Landes (Dow Chemical)
Aymeric Robert (SLAC National Accelerator Laboratory)
Jon Tischler (Argonne National Laboratory)
Michael Toney (SLAC National Accelerator Laboratory)
Jin Wang, Chair (Argonne National Laboratory)

Inelastic Excitations:
Steve Durbin, Chair (Purdue University)
Ken Finkelstein (Cornell University)

High Energy Diffraction:
John Budai (Oak Ridge National Laboratory)
Peter Chupas, Chair (Argonne National Laboratory)
Stefan Kycia (University of Guelph)
Pamela Whitfield (Oak Ridge National Laboratory)
Angus Wilkinson (Georgia Institute of Technology)

Microscopy and Imaging:
Paul Dumas (SOLEIL Synchrotron)
Steve Heald, Chair (Argonne National Laboratory)
Martin Holt (Argonne National Laboratory)
Barry Lai (Argonne National Laboratory)
Tony Lanzirotti (University of Chicago)
Michael Martin (Lawrence Berkeley National Laboratory)
Martina Ralle (Oregon Health & Science University)

Structural Biology:
John Flanagan (Pennsylvania State University)
Robert Fischetti (Argonne National Laboratory)
Sandra Gabelli (John Hopkins University)
Rebecca Page (Brown University)
Eddie Snell (Hauptman-Woodward Medical Research Institute)
Steve Wasserman, Chair (Eli Lilly and Company)
Michael Wiener (University of Virginia)

Methods and Instrumentation (members are matrixed from each panel to review only instrumentation and methods development proposals):
Paul Dumas (SOLEIL Synchrotron)
Ken Finkelstein (Cornell University)
Robert Fischetti (Argonne National Laboratory)
Stefan Kycia (University of Guelph)
Eli Rotenberg (Lawrence Berkeley National Laboratory)
Jon Tischler (Argonne National Laboratory)
Trevor Tyson (New Jersey Institute of Technology)

NSLS-II Users' Executive Committee (UEC): NSLS-II UEC is an executive committee of the NSLS-II Users Association, elected by the user community at large. The UEC serves as the official voice of the user community in its interactions with NSLS-II management. The UEC elects its Chair and Vice-Chair from among its members, and the UEC Chair has an ex-officio seat on the NSLS-II SAC. The UEC meets four times per year. The primary purpose of the NSLS-II UEC is to:

- To promote and encourage research at NSLS-II
- To provide opportunities for the user community to exchange ideas and concerns
- To communicate user needs to facility management, including the NSLS-II, Brookhaven National Laboratory, and the Department of Energy
- To broadly advocate the role synchrotrons play in the greater scientific enterprise
- To provide a channel for communicating with federal funding agencies, Congress, the White House, and other federal and state agencies.

The NSLS-II Users Association organizes the annual NSLS-II Users' Meeting in cooperation with NSLS-II, and jointly with the BNL Center for Functional Nanomaterials (CFN) Users Association. In addition, the UEC Chair and Vice Chair meet with the NSLS-II management monthly to communicate on various subjects that are of mutual interest to the users and the NSLS-II.

The UEC organizes quarterly NSLS-II UEC Town Meetings that allow the scientific user community to hear quarterly updates about NSLS-II facility development and operations from NSLS-II staff and management. At the requests of NSLS-II Director, UEC members provide input on the NSLS-II strategic plan and also participate in various taskforces that are related to user experience, amenities, and beamtime access processes.

Current membership of the NSLS-II UEC is listed below:

Jen Bohon – Chair, Case Western Reserve University
Don Weidner – Chair, Stony Brook University
Jeff Fitts – Vice Chair, Princeton University
Jean Jordan-Sweet – Past Chair, IBM
Kevin Yager – Secretary, BNL
Noel Blackburn, BNL
Paul Evans, University of Wisconsin-Madison

Sandra Beatriz Gabelli, Johns Hopkins University
Shelly Kelly, Honeywell UOP
Donald Sparks, University of Delaware
Neil Sturchio, University of Delaware
Steve Sutton, University of Chicago
Glenn Waychunas, Lawrence Berkeley National Laboratory.

***Beamline Development Process*:** All beamlines at NSLS-II are developed through calls for Beamline Development Proposals (BDPs) which solicit ideas and concepts from the scientific community concerning specific research needs and specific beamline facilities at NSLS-II. The expectation is that such BDPs will be encouraged following an initial short pre-proposal submitted to NSLS-II management. The full beamline development proposals are then peer reviewed and rated by beamline development proposal review panels as well as reviewed by the NSLS-II SAC. A typical BDP review panel consists of 5-6 external scientists from the community who are experts in the research areas relevant to the BDPs they would review. NSLS-II convenes these review panels on an as-needed basis. In the past, these review panels were convened in FY08, FY10, FY11, and FY16. The NSLS-II management takes into account these panel inputs and makes the final decision to approve or disapprove each proposal with additional input and the concurrence of the SAC.

***Beamline Advisory Teams (BATs)*:** All NSLS-II beamlines under construction utilize a Beamline Advisory Team (BAT) during their construction period. The role of the BAT is to represent the segment of the scientific user community that is expected to utilize the beamline when in operations and to advise the beamline development group on the scientific and technical scope of the beamline, and on the beamline design, to ensure that each beamline is developed to meet the community needs. During the construction phase of a beamline, the BAT typically meets once or twice each year, and they report to the NSLS-II beamline construction project manager. As a beamline plans to transition into operations, the BAT meets to discuss the commissioning activities, including making recommendations on the priority order for bringing specific capabilities into operations, and to provide advice on the early science that may be conducted at the beamline.

***User-Assisted Science Commissioning of Beamlines*:** In order to efficiently commission NSLS-II beamlines and promote the community engagement in the commissioning process, NSLS-II has developed a *phased commissioning* strategy to commission each beamline after its construction is completed. Using this strategy, scientific capabilities are commissioned sequentially based on scientific priorities determined through interactions with the BAT and user community. Once a specific scientific capability is commissioned, general user operation will commence for that capability, interleaved with commissioning activities of other capabilities. This approach permits thorough technical commissioning of all planned science capabilities while achieving early high-impact scientific productivity at the beamline.

Commissioning of each science capability progresses naturally in two phases: *technical commissioning*, where the focus is on beam delivery through the main beamline optical system into the experimental endstation, and *science commissioning*, where the focus is to evaluate the endstation instrument and data acquisition system for the planned science experiments. NSLS-II

uses direct participation of the user community during the science commissioning phase of each beamline. This is achieved by soliciting science commissioning proposals through special announcements of newly available beamlines or beamline capabilities during regular calls for General User (GU) and Partner User (PU) proposals. These science commissioning proposals are peer-reviewed and rated by the NSLS-II Proposal Review Panel for allocation of science commissioning beam time at the beamline. Review criteria for science commissioning proposals include relevance of the proposed experiments for a particular beamline capabilities being commissioned, technically feasibility and well-developed experimental plan, potential for scientific, technological, and/or societal impact beyond commissioning, and sufficient expertise of the experimental team to ensure a high likelihood of success.

Partner Beamlines and Partner Users: NSLS-II encourages and welcomes community participation in co-developing, with NSLS-II, new scientific capabilities and new scientific user communities at NSLS-II beamlines through the Partner User approach. The main objective of the Partner User program is to leverage the interest, the expertise, and the resources that may exist in the community in joint development of new scientific programs at NSLS-II. Through this approach, a partner user group may contribute cutting-edge instrumentation, new analysis software, and/or specialized staff expertise to NSLS-II beamlines to bring new capabilities online for the user community that would otherwise not available at NSLS-II. This may include the construction and operation of a complete beamline. Typically, the partner user group submits a partner user (PU) proposal through the NSLS-II proposal system, outlining the science case, the new capability, and the beamtime required to develop the new capability and its user program. The PU proposal is peer-reviewed and rated by the appropriate NSLS-II proposal review panel (PRP), and is additionally reviewed by NSLS-II management and the NSLS-II SAC. NSLS-II management makes the final decision with concurrence of the SAC.