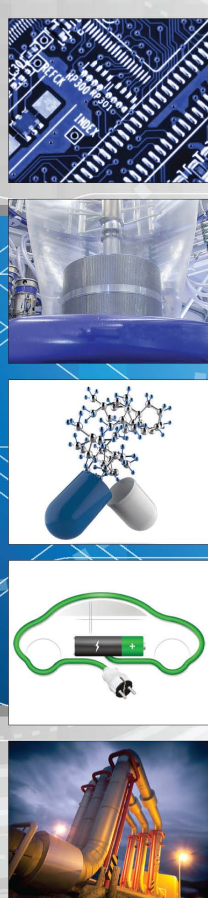

Workshop of Industrial Research at NSLS-II

A Report from the Organizing Committee

May 8, 2014

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

About this Report

On April 8-9, 2014, approximately 80 experts representing a broad cross-section from industry, national labs, international synchrotron facilities, and academia came together to explore future opportunities for industrial research at NSLS-II. A number of key recommendations were summarized in this report to help grow a strong NSLS-II program for industrial research groups.

On the Cover

The cover represents the organizing committee's vision that future innovations and transformative technologies will be driven by meshing the capabilities of the NSLS-II with the R&D needs of industry. The cover images of integrated circuits, manufacture of polyethylene film, drug design, advanced battery materials for electrical vehicles, and petrochemical pipelines represent the industries participating in the workshop. The gear suggests innovations and momentum toward the future, especially when industries such as those participating in the workshop mesh and engage with the new NSLS-II.

Workshop Organizing Committee

Chair:

Jun Wang (Photon Science, Brookhaven National Laboratory)

Gretchen Cisco (Photon Science, Brookhaven National Laboratory)

Daniel Fischer (National Institute of Standards and Technology)

Eugene Lavely (BAE Systems)

Sean McSweeney (Photon Science, Brookhaven National Laboratory)

Alexander Norman (ExxonMobil Chemical Company)

Ronald Pindak (Photon Science, Brookhaven National Laboratory)

Breakout Session Discussion Leaders

Simon Bare (UOP) --- Catalysis and Petrochemicals

Eugene Lavely (BAE Systems) --- Microelectronics

Alexander Norman (ExxonMobil Chemical Company) --- Polymers

Stan Petrash (Henkel) --- Advanced Materials

Steven Sheriff (Bristol-Myers Squibb) --- Pharmaceuticals

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Executive Summary and Recommendations

A workshop on "Industrial Research at NSLS-II", held at Brookhaven National Laboratory (BNL) on April 8-9, 2014 drew about 80 attendees, from both industry and BNL. In addition, Industrial research program managers from synchrotron facilities with strong industry policies and programs were invited to participate and most importantly to share advice on the actions needed to grow a strong NSLS-II program for industrial research groups. The workshop's success was founded upon the long, active and continuing participation of industry in NSLS activities. This history of collaboration has been productive for both sides and was clearly evident through the contributions made by the scientists who were invited to share their experiences. More importantly, the history of industrial research at NSLS fostered frank and detailed discussions concerning the path forward for establishing an environment with a strong industrial presence at NSLS-II. Breakout sessions in: Polymers, Catalysis and Petrochemicals, Microelectronics, Advanced Materials, and Pharmaceuticals brought additional sector-specific inputs, which captured a broad cross-section of US companies. It was the commonality within the contributions of our colleagues, in summarizing the conclusions of these focus groups that has allowed us to make a number of key recommendations that are described in the following.

We believe this is an opportune time for BNL to establish a new mode of cooperation with industry at NSLS-II, and we encourage the Lab management to seize the initiative in this activity.

Recommendation 1: **Establish an Industrial Liaison Team (ILT) to promote the development of a strong industrial program.** Just as there is not one type of synchrotron science there is not a single type of industrial research scientist. A key lesson from our synchrotron colleagues operating these programs is that it is necessary to establish a team with the correct competences to respond to the different needs of the industrial research community -an Industrial Liaison Team (ILT), capable of providing solutions not just data. For operational responsiveness it is important that the ILT be situated in the organization with a direct reporting line to the Photon Sciences Associate Lab Director. The team will need administrative, publicity and financial support; it should be enabled to provide cross-division solutions and would ultimately become the contact point within Photon Sciences for all commercial (and commercialization) activities. To assist in direction of the ILT an Industrial Science Advisory Committee (ISAC) should be established with composition drawn from industrial scientists with a strong interest in the use of NSLS-II. The ISAC would help with the development of opportunities with and for industry; identify industrial research priorities (feeding into the beamline prioritization process); and help the establishment of Photon Sciences strategic planning for industry service and collaboration.

Recommendation 2: **Develop and communicate a strategy to promote industrial access at NSLS-II.** To enhance the access modes for industrial research at NSLS-II the ILT will be mandated to review existing policy and propose modifications for enhanced access in the future. The policy will be generated with respect to DOE, BNL and Photon Sciences missions and will be the subject of periodic review. Particular topics of immediate interest, which are addressed in this report, include the development of flexibility in access modes adapted to the different sizes and types of industry requirements; the establishment of a structure for longer term partnerships with industry; the policy for membership of the ISAC and the cost structure of any access agreements made. The ILT should be given the target to establish an industry science presence of at least 10% of beam time across the facility and higher in areas of particular strategic importance.

Recommendation 3: **Establish common protocols of industry access at National Laboratories.** The protection of intellectual property is of crucial importance to the industrial client while governance of the facility is central to the proper operation of a user facility. It appears that there are differences in the modes and opportunities of access enabled at the various DOE Facilities, this leads to reluctance on the part of industry to work with multiple labs -an artificial barrier to collaboration has been made. We recommend that BNL takes a leadership role in establishing common, flexible and responsive policies for collaboration and interaction with our colleagues in industrial research programs. This strategy avoids redundancy of effort by industry users and BNL staff. Multiple IP templates "pre-approved" by BNL can be established that reflect specific but common concerns to users and industry. The most acceptable template can be chosen by users, and the iterative negotiation cycle will necessarily be simplified if changes are still required. In addition we encourage BNL management to review our practices with respect to intellectual property to lower the barrier to staff working with industry, in particular the legal and proprietary questions that surround this work.

Introduction

The National Synchrotron Light Source II (NSLS-II) – a highly optimized 3rd generation synchrotron - is scheduled to start technical and scientific commissioning in October 2014, while the National Synchrotron Light Source (NSLS) is scheduled to shut down in September 2014. NSLS has a long celebrated history in research partnership with industry. With the goal of enhancing industrial research at NSLS-II, a world-leading synchrotron facility, a workshop on "Industrial Research at NSLS-II" was held at Brookhaven National Laboratory (BNL) on April 8-9, 2014. The workshop brought together industry experts, scientists and administrators of industrial research programs from synchrotrons around the world to explore future opportunities for industry research at NSLS-II. Approximately 80 participants from industries, other national laboratories, academia, NSLS-II, and other departments of BNL registered and attended this workshop. The workshop provided participants with information on user access policies and ways to partner with NSLS-II, the ramp-up schedule of NSLS-II capabilities, including short-term and long-term plans for NSLS-II beamlines, plans for the transition period between NSLS and NSLS-II, and the features of existing industrial programs at different facilities. This information provided background for lively and productive discussions on the industrial research needs for different levels of scientific support at NSLS-II, the range of required synchrotron techniques, and the different modes for industrial user access at NSLS-II that best match the needs of industrial research.

In the first morning session, BNL Lab Director, Doon Gibbs, welcomed the attendees and addressed the BNL perspective on industrial research. Steve Dierker, Associate Lab Director for the Photon Sciences Directorate (PSD), presented an overview of NSLS-II and set the charge of the workshop. Scientific program planning and user access of NSLS-II was presented by Qun Shen, PSD Deputy Director for Science. The last talk, describing the NSLS-II beamline capabilities ramp-up plan, was given by Paul Zschack, PSD Photon Division Director.

The second morning session consisted of four talks presented by industrial research program managers: Edward Mitchell, European Synchrotron Radiation Facility; Elizabeth Shotton, Diamond Light Source; Jeffrey Cutler, Canadian Light Source; and Jun Wang, NSLS. Experiences and lessons learned from successfully running industrial research programs at these synchrotron facilities were shared and discussed. A summary of the points made in these presentations is included in the report.

In the afternoon session, Mike Furey, BNL Research Partnerships Manager, talked about partnering mechanisms and resources at BNL. Two presentations from Stony Brook faculty, Peter Stephens and Michael Dudley, described their experience of working with industry using synchrotron techniques. Industrial research scientists and leaders Simon Bare (*UOP*), Yan Gao (*GE*), Steve Sheriff (*Bristol Myers Squibb*), Ying Shi (*Corning*), and Kyle Litz *(Auerra Inc.*), presented their research performed at NSLS. They discussed the impact of synchrotron facilities on their projects and ways they would like to work with

NSLS-II in the future. The presentations from industrial researchers covered topics of both proprietary and non-proprietary interest. A wide cross-section of scientists representing S&P top 500 companies and small, startup companies actively discussed their needs and proposed recommendations for NSLS-II. A tour of NSLS-II followed after the presentations in the evening (see Appendix 2 for the complete workshop agenda).

The next day was devoted to breakout sessions covering five different industrial sectors. Specifically, the workshop participants were divided into groups to discuss specific needs in the fields of polymers, catalysis and petrochemicals, microelectronics, advanced materials, and pharmaceuticals, which represent important sectors of US industry. The enthusiastic discussions at the workshop made it evident that there are strong mutual interests and benefits for industry and the synchrotron user facility to work together. There were a number of recurring themes that emerged from the discussions as ways in which industry and synchrotron user facilities could work together more effectively.

The recurring themes were summarized as three key recommendations: (1) Establish an Industry Liaison Team (ILT) to promote the development of a strong industrial program; (2) Develop and communicate a strategy to promote industry access at NSLS-II; and (3) Establish common protocols of industry access at National Laboratories. These recommendations are covered in detail in the next section.

Recommendations

***Recommendation 1*: Establish an Industrial Liaison Team to promote the development of a strong industrial program**

A key lesson from our synchrotron colleagues operating industrial programs is that it is necessary to establish a team with the correct competences to respond to the different needs of the industrial research community - an Industrial Liaison Team (ILT), capable of providing solutions not just data. At the ESRF, such a group has five full-time employees with other resources to call upon; finance, legal and administrative support. Diamond Light Source has seven scientists comprising the industrial liaison group. The Canadian Light Source has seven staff dedicated to work on industrial research.

This was also the strongest recommendation identified in the five industrial research breakout sessions. The ILT would help to deliver what many industry users ultimately desire: "Not data, but answers". The pharmaceutical community emphasized that the NSLS-II ILT should be at least the equal of those available at other facilities like ESRF, DLS and CLS.

To assist the ILT in developing and implementing effective industrial programs, an Industrial Science Advisory Committee (ISAC) should be established with composition drawn from industrial scientists with a strong interest in the use of NSLS-II. The ISAC would help with the development of opportunities with and for industry; identify industrial research priorities (feeding into the beam line prioritization process); and help the establishment of Photon Sciences strategic planning for industry service and collaboration.

For operational responsiveness, it is important that the ILT be situated in the organization with a direct reporting line to the Photon Sciences Associate Lab Director. This will enable ILT to provide cross-division solutions and ultimately become the contact point within Photon Sciences for all commercial (and commercialization) activities. ESRF, DLS and CLS structure the ILT to directly report to the facility director.

Elevating the importance and visibility of the ILT is also a key strategy to increase industrial usage of NSLS-II. The ILT should be the first and obvious point of contact for industry; ILT staff can best coordinate the industrial users' interaction with BNL and its affiliated universities and government laboratories. In addition, the ILT should have the mandate and budget to proactively engage industry, and jointly craft with industry a vision and implementation plan for access and service that best meets the needs of industry, while at the same time developing the resources, expertise, and a service model that may more broadly impact interactions with users. Beamlines tend to be technique-centric, or technique-dominated, whereas the ILT has the opportunity to be domain-centric, and integrative of the multifaceted capabilities of the lab. This approach highly supports industry engagement, and is a potential model for academic interaction as well. The ILT can make the case of why users should come to NSLS-II, not only in terms of unique facilities offered by the synchrotron, but the state-of-the-art processing algorithms, the expert staff, the user-friendly service model, and the undeniable return on investment.

***Recommendation 2*: Develop and communicate a strategy to promote industrial access at NSLS-II**

To enhance the access modes for industrial use of NSLS-II the ILT should be mandated to review existing policy and propose modifications for enhanced and rapid access. The policy will be generated with respect to DOE, BNL and Photon Sciences missions and will be the subject of periodic review. Particular needs of paramount importance and interest to industrial users that the policy should address include: **the development of flexibility in access modes and cost structure adapted to the different sizes and types of industry requirements**; **the establishment of a structure for longer term partnerships with industry; and rapid access for industry.**

Another policy issue that impacts all proprietary modes of industry access is the amount of proprietary beam time available at what are anticipated to be highly oversubscribed beamlines. It is recommended that a fraction of beam time at a suite of beamlines at NSLS-II be made available for proprietary use, with the maximum amount capped at a pre-determined level, which could differ from beamline to beamline. This beam time would be taken from-the-top, before general user allocation. Initially, the suite of beamlines with the largest fraction of proprietary beam time would include beamlines supporting the techniques of X-ray absorption spectroscopy, X-ray diffraction, PDF, SAXS, and imaging. Nonetheless, access to more specialized higher-performance beamlines is also needed.

It was recommended that flexibility in industry user access could be best achieved by a tiered approach from a consortium partnership, to individual general user, to fee-for-service modes. ***Depending on the particular need an industrial lab could use the access mode that best matches the need.***

<u>Consortium Access</u>**:** One major outcome from discussions is the proposal to establish an Industry Users' Consortium (IUC), based upon the successful model of consortia that have previously been established e.g., Synchrotron Catalysis Consortium, COMPRES, CARS, etc. The intent of an industry users' consortium (IUC) at NSLS-II is to enable members of the consortium to access appropriate beamlines for their R&D needs in a timely manner and with a guaranteed amount of beam time. The consortium would be open to all companies headquartered in the US. Each member company would pay a membership fee, and the amount paid would determine the amount of beam time that each company is allocated. There are many different models that could be used for the fee structure, and is a policy detail that needs to be discussed further. This is a model for collaborative research with pooled resources. By making a common investment, members of the consortium can benefit from joint investment, yet still retain proprietary rights and competitive/economic advantage. This model is well known in the highly competitive microelectronics industry e.g., Sematech, so its adaption and use by the lab should be acceptable if not familiar to other potential industry clients and users. Having a consortium implicitly demonstrates the value of the facilities to industry, and can be used as a leverage point to gain funding from one or more agencies from the government for a beamline dedicated to industrial research and service.

Proprietary General User Access: In cases where the access needs to be proprietary, what is preferred is a proprietary access mode with the added flexibility of beamline staff signing a non-disclosure agreement (NDA) with the industrial user. This would ensure the active involvement of the beamline staff in setting up strong collaborative efforts between NSLS-II and industry rather than NSLS-II just becoming a large center of data generation. It was discussed that NSLS-II will have world-class facilities and expertise, and that collaborative work is necessary to fully enable exploitation of these capabilities across the multiple industry sectors.

Rapid General User Access**:** Time-to-market and the rapid pace of innovation are vital features of the competitive landscape. Therefore, it is crucial to provide rapid access for quick turnaround, and to provide the required technical and practical support for meaningful and actionable results. Therefore the flexibility, provided to PRTs at the NSLS, is very important at NSLS-II as well, as proposal preparation and adherence to the submission cycle timelines and review periods can be inconsistent with the product development deadlines and market cycles that drive industry users working in a competitive environment. A low-energy barrier is essential, as once the green-light is granted by industry management, it is sometimes essential to complete the experiment as soon as possible due to product development cycles, timelines, costs, and process dependencies within the organization. Bringing the design, fabrication, and assembly of products to commercialization without delay in these cases is paramount.

Fee-for-Service Access: For smaller companies, especially ones that do not have knowledgeable researchers who can fully interpret data, providing analyzed data for a fee can be an effective alternative. Developing a cost structure and methods to ensure quality of results is crucial. Mail-in sample service is another tier of access to provide rapid turnaround where the beamline staff simply provides the industrial user with raw data under a proprietary access mode.

Automation and Remote Access: Industrial R&D needs require the development of highly automated beamlines with high sample throughput for some key workhorse characterization techniques e.g. XRD, XAFS, micro- and nano-tomography, high energy diffraction, that are much sought after for industrial research. These beamlines should have the capability for remote access from the home institution where feasible and the implementation should be reliable and based upon accepted standards. Reproducibility of results is often essential, so careful recording of experiment parameters, protocols, and sample preparation must be supported.

Coordinated Access across Scientific User Facilities: There are techniques common to multiple national synchrotron facilities, so it is worth considering pooling resources e.g., for common data processing and imaging algorithms in order to better advance the science and reduce duplication of effort.

Recommendation 3: **Establish common protocols of industry access at National Laboratories**.

We recommend that BNL management takes a leadership role in establishing common, flexible and responsive policies for collaboration and interaction between facility staff and industrial researchers. In addition we encourage BNL management to review BNL practices with respect to intellectual property to lower the barrier to staff working with industry, in particular the legal and proprietary questions that surround this work.

The protection of intellectual property is of crucial importance to the industrial client while governance of the facility is central to the proper operation of a user facility. It appears that there are differences in the modes and opportunities of access enabled at the various DOE Facilities, this leads to reluctance on the part of industry to work with multiple labs -an artificial barrier to collaboration has been made.

Protection of the IP rights of a company is of critical importance to many clients. This is true for the IP issues as expressed in the contract with BNL and the protection of the integrity of the samples and derived data. For the pharmaceutical group, the possibility of error in data collection i.e., inappropriate transmission of information, was considered too significant an issue to be allowed to happen - this has implications for automation and data confidentiality at NSLS-II.

It is clear that more flexibility and simplification of DOE policies regarding IP issues is needed to better build industrial usage of the scientific user facilities. New models for IP protection for engaging with US industry should be examined.

Summary of Industrial Research Program at ESRF, DLS and CLS

1. Industry Solutions at European Synchrotron Radiation Facility (ESRF)—Edward Mitchell, Head of Business Development, ESRF

Industry usage and access:

- 40% of the science done using public beam time has links to industry ;
- Confidential facility access with on-site, rapid access and mail-in, generates 1.5-2 M Euro ($2.1M- $2.8M) per year, 100 unique clients per year;
- 2% beam time in average overall the facility to industry, with celling 30% on single beamline and 10% across the facility for proprietary access.

Organization: reports to ESRF Director General

- 5 FTE + other resources (call upon finance, legal, admin for support as well as the goodwill of all ESRF staff to work with industry)
- Group: 2 structural biology scientists, 2 imaging scientists, 1 soft matter scientist, 1 instrumentation engineer, 1 admin coordinator (part time), 1 manager. Expertise covers MX, High-resolution diffraction, microtomography and topography

Responsible for all ESRF industrial activities:

- Industrial access to beamlines, facilities, and expertise;
- Technology transfer through licensing, patents, spin-off;
- Manufacturing; when a tech transfer Is not worthwhile, we directly manufacture ourselves and sell, mostly, instrumentation to other light sources
- European and national funding opportunities

Cost structure:

- 3600 Euro (~$5000) standard per 8 hour shift ($620/hr) is the basic fee for beamtime and includes set-up and start-up training
- Fee varies around this for high intensity/high throughput beamlines
- Fixed price per sample for mail-in with rapid access for MX, bioSAXS, SAXS, PDF
- Customized quotes for mail-in tomography, powder diffraction, spectroscopy… and
- Contract R&D, including combined facility and partner work;
- Scientific support is charged at 175 Euro ($240) per hour

Strategy:

- Provide answers industry wants
- Provide feasibility studies
- Increase capacity to provide high service level
- Provide training/education to enhance non-expert awareness, access and use
- Work with other institutes, including other light sources, neutron, to organize targeted joint workshops, to apply for joint funds, and to explore opportunities to work together.

2. Industrial Research and Technology Service at Diamond Light Sources (DLS)—Elizabeth Shotton, Head of Industrial Liaison, DLS

Access modes:

- Proprietary access (paid for): up to 30% on an individual beamline with a cap 10% overall beamtime; Confidential results (No IP issue) or results publishable but guaranteed access
  - Beamtime only: priority access; pay for what you need; ideal for experts; day, shift, or hour
  - Mail-in data collection service: 1-100s samples, rapid turnaround, multiple techniques. Emphasis on automation (acquisition, sample changes, data processing pipeline)
  - Remote access (MX): collect data from home institute; minimize travel; all team can participate
  - Consultancy: dedicated scientific team, from experiment design to reporting
- Non-proprietary access (No charge):
  - Shared results: collaboration with Diamond, e.g. EU grant funded work
  - Results publishable and no guaranteed access: Free access through peer review

Outreach:

- Customized marketing material
  - Dedicated website: 30 Industry case studies;
  - Industrial sector flyers
  - Beamline flyers
- Industrially-focused conferences, industry news
- Collaborative research

Outcomes:

- 72 companies over 12 countries, and expanding
- 450% change in income in fy13/14 compared 100% in fy08/09

Organization:

- Industrial liaison group reports to Diamond Board & Diamond Executive

- 7 scientists including 1 manager and 1 software scientist.
- Scientist expertise (XAS, XRPD+ Engineering, SAXS, MX, Software)
- Diamond Industrial Science Committee (DISCo) reports to Diamond Board & Diamond Executive

3. Industry Services at Canadian Light Source (CLS), Jeffery Cutler, Director of Industrial Science, CLS

Strategic Planning:

- One of the three goals of CLS strategic planning for 2013-2017 is to be the most responsive and valuable synchrotron facility for industry.
- Objectives: Be seen by industry as the most attractive facility to conduct synchrotron-based research; 2) Grow industry relevant scientific expertise; 3) Develop industry - relevant research infrastructure

Modes of access:

- Purchased access: First com- first served; market price; turn-key analysis, courier model, fully confidential, IP owned by industry
- Collaborative access: Commercial collaborations; academic but apply fee for service; service fees, recover some operations & overhead costs, intend to selectively publish
- Peer-reviewed access: academic, self-service, intent to publish

Up to 25% time on all beamlines set aside for first-come first-serve users, IP ownship clearly identified, rapid access an important consideration in scheduling access

Partnerships Modes: of industrial engagement. 1) Strategic research 3-5 yrs, with several industrial partners; 2) collaborative research 2-3yrs, with one or two industrial partners; 3) Analytical service <6 months, purchased access, fee-for-service

Organization: Director of industrial science reports to Executive Director of CLS, equal input to decisions as directors of research, accelerators, technical support. 7 Staff including 5 scientists, 1 manager, 1 admin.

Engagement + Analysis Targeted sectors: Earth and environmental (Mining metals, Oil+Geo); Material and chemical (Aerospace, Automotive, Petrochemical, Energy storage); life (Agricultural, Pharma)

- Identify important industry tradeshows and conferences
- What industries work in this area
- Any relevant academic research centers or centers of excellence
- Capabilities to be developed at CLS
- Marketing ideas and ideas for one pagers
- Strategies for engagement for industry
- Potential areas of research with industry

- CLS facilities that align with sectors

Fee structure and IP:

- Beamtime - $500 per hour. Staff Time - $150 per hour (billed for sample preparation, analysis and report writing)
- proposed academic rate (publishable): $250 per hour for BT, $50 per hour for staff time
- Adopted intellectual property policies that are beneficial to the client

CLS only retains the proportionate share of ownership of intellectual property developed by its staff.

Risk Management: Carefully manage risks to have plans in advance to help maintain your community.

Microelectronics Discussion Group

Eugene Lavely, BAE Systems

Summarize needs of industry in microlectronics field – not technical, but access – rapid access? Proprietary? Support? Paid service? Consortia?

Access:

- The amount of work required to gain management approval for synchrotron research, and to prepare and submit a proposal can be very difficult for industry, particular for first-users of synchrotron facilities. The application process is competitive, and the timelines of proposal submission cycles may not be consistent with the market-driven needs of industry. One suggestion is to reduce somewhat pure-research at synchrotron beamlines to enable more industry use, or at least until such time that more beamlines become available, as there is oversubscription currently. Access should recognize that there are three types of users. The *first* type of user knows how to use the system, and so perhaps a service oriented mission could support those users, particularly for mail-in. The *second* type of user has more interest in a particular type of technique, and more in-depth knowledge than the first type of user, and may wish to work interactively with beamline staff to understand the data and best achieve the goals. This is more of a typical scientific collaborative relationship. The *third* type of user, the most advanced one, wants control over one or more techniques and would like whole beamline to develop instrumentation. All three modes of access should be available so that the return on investment from the user can be identified and implemented in the mode most appropriate for the need.
- In terms of rapid access, the microelectronic industry work mode is highly coupled and inter-dependent. Time-to-market, and the rapid pace of innovation are paramount features of the competitive landscape. Therefore, it is crucial to provide rapid access for the appropriate turn-around, and to provide the required technical and practical support for meaningful and actionable results. Therefore PRT flexibility is very important here as well, as writing a proposal and adhering to the submission cycle timelines and review periods is inconsistent with the product plans and market cycles of the industry users. A low-energy barrier is essential, as once the green-light is granted by management, it is essential to complete the experiment as soon as possible. Process, fabrication and assembly are human and plant intensive, and rapid insertion without delay is paramount.

Support:

- Microelectronics is a strongly competitive industry, and is also crucial for the national economy, it is not a niche area. For that reason, the lab should make an effort to recruit and support staff and beamline scientists with in-depth knowledge of microelectronics, to advise users on experiment design, the capabilities and applications of the techniques, and on best practice. It is important to maintain this knowledge in-house for continuity, and also to train post-docs who can then return to industry so that there is a community of specialists at the labs and within the companies.

- The support should range from the highly collaborative to simply “just give me the answer” in service of the entire spectrum of microelectronics users. Some microelectronics companies support advanced research, and the scientists using the beamlines can sometimes share their capabilities, processing methods, and insights. Reciprocity between the staff and the users of the lab promotes better techniques, science, and results for all users.

Cost:

- There are limited budgets at the synchrotron labs, and so it is recognized there may not be enough staff to provide the degree of support required by all users including industry. However, if an investment is made to increase support for users, and on a payment basis, then the level and quality of support can increase, and this can lead to a virtuous cycle for increasing industry use, and therefore increasing funds available to the beamlines to hire staff with the requisite expertise and availability. As in academics, employees in industry develop collaborative relationship with colleagues, and maintaining that continuity is important, including having overlapping staff as each staff member moves to the next stage of their careers.

Recommend preferred mechanism for NSLS-II access – Tier-2 (mail-in), high-tech, rapid-access high-volume get data back, or high level technologically demanding experiments

- The number one criterion here is flexibility as the absence of it is a showstopper. The problems and issues for microelectronics are numerous, but there are bound to be commonalities. These should be identified, and there should be as smooth and quick glide path as possible that is already sorted out and in place. The procedures and required processes relevant to the industry should be available as “templates”, in a sense, to expedite transactions, and minimize repeated interactions between the lab and the industry customer that are required to reach agreement, and to obtain the service. Industry operates on a different time line than pure research, or academics, and this must be recognized, flexibility is key for the former.

Increase industry usage – how does NSLS-II do that? What would make that happen?

- Successful case histories should be publicized. Relevant published works should be highlighted. Lab attendance at relevant trade associations and professional meetings with booth staffing should be supported. An obvious technical advisor or referral source at the Industrial Liaison Team (ILT) should be easily identifiable to the prospective user. The BNL web site should highlight microelectronics applications of the beamline. Relevant techniques and beamlines should be defined at several possible portals. BNL should make proactive contacts to industry to alert them of the capabilities, particularly for companies that have not yet used the beamline. It should be shown that the services can provide a competitive advantage, reduce time to market, support rapid innovation, etc.

- A key strategy will to elevate the importance and visibility of the ILT. This should be the first and obvious point of contact for industry, and advisers there can best coordinate the user interaction with the lab. In addition, the ILT should have the mandate and budget to proactively engage industry, and jointly craft with industry a vision and implementation for access and service that best meets the needs of industry, while at the same time developing the resources, expertise, and service model of the lab. Beamlines tend to be technique-centric, or technique dominated, whereas the ILT has the opportunity to be domain-centric, and integrative in a sense, of the multifaceted capabilities of the lab. This approach highly supports industry engagement, and is a potential model for academic interaction as well. The ILT can make the case of why users should come to NSLS-II, not only in terms of unique facilities offered by the synchrotron, but the state-of-the-art processing algorithms, the expert staff, the user-friendly service model, and the undeniable return on investment

Microelectronics Research Consortium:

- NSLS-II could facilitate microelectronics industry participation by adopting the SEMATECH model (see www.sematech.org). This is a model for collaborative research, and with pooled resources. By making a common investment, members of the consortium can benefit from joint investment, yet still retain proprietary rights and competitive/economic advantage. This model is well known in microelectronics, so its adaption and use by the lab should be familiar to the potential microelectronics clients and users.
- In addition, there are techniques common to multiple of the national synchrotron facilities, so it is worth considering pooling resources e.g., for common data processing and imaging algorithms in order to better advance the science and reduce duplication of effort.
- Having a consortium also implicitly demonstrates the value of the facilities to the government, and can be used as a leverage point to gain funding from one or more agencies from the government for a beamline dedicated to microelectronics research and industry service.

The range of techniques needed for microlectroncis research:

- Full field transmission tomography (TXM) for imaging of structures such as nterconnects, vias, and contacts. TXM may also be useful for fault isolation e.g., voids due to electromigration.
- Differential absorptions contrast with TXM for chemical specificity of IC components, and which can be used, for example, to obtain 3D interconnect maps for Aluminum or Copper materials, or to isolate Tungsten contacts from the remainder of the structures.
- XRF for quantitative estimation of 3D chemical maps of IC structure, and possibly for fusion with TXM results. XRF may also be useful for thin film quantification, and chemical identification of diffusion barriers.
- XANES for identify oxidation states in IC i.e., Copper metallization oxidation states with respect to thin film or diffusion barrier interfaces

- High-resolution diffraction (XRD) for measurement of thin films and characterization of strain states, characterization of material phases upon annealing, and defining texture in films.
- Near-edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy for characterization of nanoparticle assemblies

Polymer Discussion Group

Alexander Norman, ExxonMobil Chemical Company

Several breakout sessions concluded the Industrial Research at NSLS-II meeting held on April 8-9, 2014. One breakout session was centered on industrial research needs in the polymer arena.

The topics for discussion included:

- General needs of the polymer industrial users
- Access modes to NSLS-II for industrial users
- Ways to increase industry usage and impact on NSLS-II

<u>General needs for industrial users</u>

The most obvious conclusion was clear as discussions were initiated: Industrial users in the polymer field want scientific support and input of the beamline staff. Dedicated, enthusiastic beamline staff would rapidly facilitate data generation since finding professors with experienced graduate students to perform synchrotron measurements and analysis can be a challenge. For non-proprietary access, this is not a problem. However, some discussions followed regarding proprietary access. Concerns included inability to publish material, and then a perceived negative performance measurement of the beamline staff from BNL. It was pointed out that industry would rather access NSLS-II via a proprietary access mode to simply have the ***flexibility*** of running both proprietary and non-proprietary samples. Under this mode, industry would get the scientific support necessary from the beamline staff, and the beamline staff would be able to publish some of the data, once cleared from the users' law department. Users would also prefer a rapid proprietary access mode simply because a non-proprietary access is a lengthy process requiring proposal writing, and external review. The main user need for industry is ***flexible*** and ***rapid access***.

<u>Access modes to NSLS-II for industrial users</u>

The points made above regarding ***flexibility*** and ***rapid access*** dictate the access modes to NSLS II for industry. What is preferred is a proprietary access mode with the added flexibility of beamline staff signing a non-disclosure agreement (NDA) with the industrial user. This would ensure the active involvement of the beamline staff and setting up strong collaborative efforts between NSLS-II and industry rather than NSLS-II just becoming a large center of data generation. It was discussed that NSLS-II will have world class facilities and world class expertise and to fully exploit this across industry, collaborative work is necessary.

The possibility of a rapid, mail-in sample service was discussed. While useful for some industrial projects (e.g. 100 samples of very similar nature, but processed slightly different or with a slightly different additive content), the real advantage of NSLS-II is its superior brightness and ability to perform demanding, complex experiments. Many polymer users from industry do have some experience and will want to bring their own equipment to the beamline (e.g. fiber spinner, extruder etc.)

It was concluded that a two-tier access would be advantageous: (1) Mail-in sample service for rapid turnaround where the beamline staff simply provide raw data back to the user under a proprietary access mode, and (2) Proprietary access mode, with a NDA signed by NSLS-II staff, to become more involved in the industrial user experiment. The industrial user can also perform some experiments under this mode that are non-proprietary in nature which ensures some possibility of publications for the NSLS-II staff.

Ways to increase industry usage and impact of NSLS-II

Many scenarios were discussed as to how to increase the number of regular industry users. No clear conclusion was apparent. However, what was decided was that there should be a Polymer Workshop at NSLS-II to further discuss this. Potential avenues are: Focus Groups, Polymer Research Consortium. Such a consortium would have a nominal fee per year in exchange for an annual meeting to discuss further needs of the industrial users on the specific beamlines. Such a fee could go toward providing specific shared sample instrumentation.

Pharmaceutical Industry Discussion Group

Steven Sheriff , Bristol-Myers Squibb

The representatives at the Pharmaceutical Industry Interest Group (PIIG) covered the spectrum of industrial participants from small research and service providers through to people working at multi-national companies. Despite this disparity broad consensus was present within the PIIG on the improvements necessary to provide a strong incentive for the use of NSLS-II:

1. *Ease of access and rapidity of contract turn around*: In comparison to other US synchrotron facilities it is perceived that BNL suffers from being less flexible in its access terms and is significantly less responsive in getting to the point – a signed contract.
2. *Protection of the IP rights of the company*: expressed in both the contract wording and the protection from ensuring the security of the integrity of the samples (Never ever mix up samples) possibility for error in data collection (from mixing data sources) was considered too important to be allowed to happen - this has implications for automation and data confidentiality at NSLS-II.
3. *Regular access to beam line for data collection*: depending on the size of the project portfolio this need ranged from weekly to monthly access.
4. *Speed and volume of the data collection capacity*: to be attractive NSLS-II must provide services that are at least the equal of those available at other facilities.
5. *Beam line needs*: in general it is felt that cutting-edge beam lines were not the prime driver for the PIIG - samples tend to be well characterized and with reasonably strong diffraction properties. Of greater concern was mature, reliable automation based upon accepted standards.

Advanced Materials Discussion Group

Stan Petrash, Henkel

The Advanced Materials Breakout Session was structured around the natural timeline of performing the synchrotron experiments, from identifying the needs for synchrotron techniques, to getting the buy-in from the company's management, to experiments themselves and finally to the communication of results to the industry and government stakeholders. Each section, with relevant issues that were discussed, is presented below in chronological order.

1. Identifying the Need for Synchrotron Techniques

The attraction of the synchrotron techniques (as compared to regular techniques) is two-fold:

1. Some powerful techniques, such as X-ray Absorption Spectroscopy, as simply unavailable outside of light sources, so the need for the synchrotron experiments is natural.
2. The synchrotron-based "conventional" techniques (powder diffraction, scattering, etc.) are attractive to the industry because of the flexibility of the beamline setups, which allows many in-situ/in-operando experiments that are critical for such industry-specific tasks as process development.

An issue of industrial participation in the process of developing brand-new techniques and/or building the beamlines was discussed. The consensus was that the companies would prefer for techniques/beamline being built by the facilities, in collaboration with academia, since those have the most expertise in their field. However, it was deemed critical for success to have industrial scientists to participate in BATs (Beamline Advisory Teams), to accommodate industry-specific needs for sample dimensions, sample environment, etc. All too often the beamline design is tailored 100% to academic priorities and by the time industry bring up their own specific requirements (such as sample size, or quick turnaround, or ability for remote control, etc.), it is too late in the design/construction process to accommodate those. For instance, one of reason DuPont was able to sign a 15-year agreement in the past was that they had a direct input into design process of the beamline, so later for them it was difficult to walk away from such investment.

To ensure the success of new techniques and to ensure a steady inflow of industrial users, early communication about the new capabilities was deemed important. When communicating to the industry, the emphasis should be placed not on "newness" or "world-beating resolution" or "uniqueness" of new beamlines, as those words set alarm bells in the heads of decision-makers, translating in "expensive", "hard-to-reproduce" and "hard-to-understand". Instead, the emphasis should be placed on "speed", "throughput", "reliability" and the ability to operate in "industry-relevant environments", at "production speeds". One industrial scientist made a comment that words like "nano-sized, super-coherent beams" scare him, he would be more comfortable with regular diffraction that provides him with reliable, high quality conventional results.

A critical key to success would be early industry-focused workshops, to which industrial scientists can bring a few samples "just to try and see what happens", and to get comfortable with the technique(s), lowering the barrier of entry.

2. Choosing an Appropriate Facility.

It was perceived important that prospective industrial users should have a good understanding of what they should expect from the synchrotron experiments, when they look for the facility/technique/beamline to satisfy their needs. Two main "point-of-contacts" at the synchrotron facility were identified, based on the experience level of a prospective user:

1. For the first-time users and those only getting into synchrotron research, Industrial Relations Office is a good first point of contact. They can guide users to an appropriate technique or suggest a more suitable alternative to conducting experiments at a synchrotron. Single point of contact for technical and administrative work is important in this interaction.
2. For more experienced users, the first point of contacts would be beamline scientists, who would handle the technical issues, with later hand-off to the Industrial Office to process paperwork.

At this point the discussion focused on a very important issue of beamline scientists having the ability of control over beamtime allocation in order to run small-scale feasibility studies, lowering the barrier of entry for a potential industrial user. The beamline scientists and/or Industrial office should have pre-allocated blocks of beamtime that can be given to potential users for small feasibility studies. If those blocks are not used, they can be returned back into general beamtime pool.

The facility system should have a process of evaluating success of beamline scientists in creating new connections with the industry and reward this activity accordingly. To facilitate that, the Industrial Liaisons should sit high enough in the Facility's Org Chart (like they do in Canadian Light Source), so they can have an impact on rewarding those beamline scientists who make extra efforts in working with industrial customers with better career prospects.

3. Getting Buy-in from Company's Management

Handling of Intellectual Property (IP) was deemed one of the key issues that can make or break potential collaboration with synchrotron. If IP stays with academia or the Government, even if partially, it will kill many potential opportunities. It was seen important to work on lowering the barriers of entry (high initial level of monetary contribution, long-term commitment, long proposal review times, lack of "rapid access") to make the job of selling synchrotron experiments internally easier.

Work needs to be done on changing the perception of what synchrotron work is all about. The common perception is that the goal of synchrotron work is mostly about doing fundamental science and publishing in prestigious journals. Facilities should not only publicize the cutting-edge science, but also highlight applied, relevant to industry research. Synchrotron marketing literature should target two audiences: a) industrial scientists with detailed scientific info, as well as, b) management decision-makers, with easy-to-understand, brief and highly visual material. Emphasis on exotic techniques may scare management away, being generally perceived as too risky, too expensive and, perhaps more important, too far away in the future to make an immediate impact on the bottom line. Emphasis should be made that synchrotron facilities are often the only place where some industry-relevant experiments can be conducted.

Quality assurance for the data might be an important selling point, most industry sectors place high value on consistent, reproducible datasets. It would be good that some calibration/quality assurance would be "built into" the beamlines, so users don't have to spend their own beamtime each time to run standards need to collect extra data for QA purposes. There was a commonly-shared view that most of the industrial customers would be willing to pay extra for that kind of certification.

One of the key factors that may make company's management to approve the synchrotron work could be the evidence that their direct competitors are using synchrotrons as well. Those who already using the facilities would be more apprehensive about stopping an ongoing collaboration, for the fear that their competitors will take their place instead. On the other hand, some company might be apprehensive about working in the same facility as their competition, for the fear of information leaks.

4. Applying for and Getting Beamtime

Four different modes of access were presented to the members of the breakout session, from least involved to most involved, and participants were invited to show hands who would be interested in each respective mode of access. The results were as follows.

1. "Just Try Things…" (send sample, see what happens) – all voted enthusiastically
2. Rapid Access (proprietary paid access ~3 month time scale) – all voted enthusiastically
3. General Proposal (free beamtime within 6 month) – moderate enthusiasm
4. Consortium ("Partner User"; annual payment with guaranteed beamtime) – no enthusiasm, not well-understood

The results of that exercise was that the first offer from the facility to the industrial user should always be "let's just try things" and not "let's sign a one-year commitment". This long-term commitment may develop down the road, but it will not be there from the beginning. This commitment can be obtained after a series of proven successes and after all previous steps have been tried, with long-term commitment would be proven to deliver the best value than the alternatives.

The lesson here is that the new facility may not necessary needs to invent a brand-new mode of access, but merely reprioritize the order with which the facility presents the options to the potential ling-term users. When industrial customer will develop an ongoing need to utilize the synchrotron experiments in their R&D process, the Partner User arrangement will be much more attractive.

The comment was made that industry does not want "health club membership" model of agreements. For some companies long-term commitment may make sense, but for many it is simply not viable, due to constantly shifting priorities. In the current economic climate, the goal of synchrotron facility should be to gain (or retain) those industrial customers that are one or two tiers below industrial giants such as IBM, GE, DuPont, etc. The best mode of access would be: defined benefits for defined costs.

Due to the variety of technology needs within one company, it would be important for Partner User to have guaranteed access to more than one beamline at the facility, or even preferred access to other facilities under the DoE umbrella, if the agreement with one DoE facility already exists.

For companies like DuPont *priority access* to other facilities via Partner User agreement would be very attractive, since even the technical needs of company like DuPont will change over time. Canadian Light Source chimed in that that's what CLS already doing, to the point that an academic user was sent home (with paid tickets) without beamtime to make space for a priority industrial customer. Would BNL be able to do such thing?

Everyone was in agreement that proposal review panels need a mix of industry and academic scientists, or have a separate review panel dedicated to the reviewing and grading of industry proposals. One comment was that awareness about potential conflict-of-interest between industrial competitiveness is needed, (for proprietary proposals only). However, it was not of a main concern, since conflicts of interests exists in academic environment as well.

Another issue that was discussed is the reluctance of companies to disclose relevant internal data in beamtime applications. Reviewers from academia may perceive the proposed experiments that appear to lack lots of prior published work as not important or well-thought out. However, the exact opposite might indeed be the case. The MORE important a synchrotron experiment is to the company, the LESS detailed background information industrial applicants will provide in the beamtime application. Reviewers from the industry are familiar with this phenomenon and will take this into account when grading proposal, but academic reviewers may not.

5. Conducting the Experiments and Data Analysis

Again, several options of different models of conducting experiments were presented to the panelists.

1. Mail in access – lots of interest
2. Remote access – lots of interest
3. On-site access – lots of interest
4. On-site staff - moderate interest

The latter mode generated lively discussion, since the possibility of having industrial representatives working permanently on-site at the synchrotron light source was perceived as the key point for ensuring long-term health of industry-facility collaboration. Not only such embedded staff (be it an industry-sponsored postdoc or a grad student, or a member of company's staff) would greatly assist in reliable collection and proper interpretation of the raw data, it will help to deliver what the industry ultimately wants: "Not data, but answers". These embedded students and postdocs, upon demonstrating value to the company, would most likely be later hired to become permanent staff, expanding the "gospel" of synchrotron technique within industry.

It was suggested (and enthusiastically received by the panelists) to have a system where the facility and the company would split the costs of financing for the "embedded scientists" 50/50, with such scientists being 100% dedicated to industrial work. It was perceived as a "win-win" for all parties. Not only company benefits by getting a good value, but facility would inevitably benefit from the work of "embeds" as well. They will act not only as a pair of extra hands, but as a mechanism of spreading the experience in working on industrial projects across other beamlines and techniques.

Another key point in ensuring success of industrial experiment was the necessity of good communication between industrial partner and beamtime scientist. It was seen that triggering scientific curiously about the industrial problems (which might be just as interesting and challenging as the academic research) was a key to a cooperative relationship.

6. Spreading the Word amongst Industrial and Government Stakeholders.

To build on the last point, however, just satisfying a scientific curiosity alone might not be enough to serve as a proper incentive for beamline staff to cooperate with the industry partners. Facility management should have defined criteria by which success of industrial collaboration can be evaluated in the process of review and career advancement of beamline staff. There has to be a formal feedback mechanism from the industrial partners to the facility management to communicate about extra efforts of beamline staff that made an industrial experiment successful. A post-experiment conversation between the industrial liaison office and company's scientist is a good practice, but more must be done to make sure that industry's feedback is properly captured and positively influences the career development of synchrotron scientists. On the other hand, beamline staff need proper tools to be able to make a difference, like have a control of beamtime allocation to accommodate industrial users.

Likewise, companies can do more to recognize good contributions of beamline staff to their projects. Invitation to give presentation at company HQs, honorary titles of "Associate Fellow", moderate monetary awards or travel grants can all serve as solid evidence of value that beamline staff is delivering to the company.

In terms of *quantification* of contribution of staff to the industrial research, the issue is more difficult, since most of the results may never be published and patent publications take years. The number of industrial experiments multiplied by the market capitalization of the each client may serve as a rough metric, along with the number of small- and medium-size customers. It was perceived that facilities and industry together can do a better job communicating the benefits of synchrotron research to funding agencies, since, at least in theory, the impact of industry-focused research on a society as a whole should be easier to evaluate than an impact of publication of a paper in Science or Nature.

Catalysis/Petrochemicals Discussion Group

Simon Bare, UOP

Issues Critical to Industrial Users

As a preface we note that while we have tried to be comprehensive in our thinking and deliberations it is short sighted to think of "industry" as a single entity. There will never be a one-size-fits-all approach that satisfies the needs and requirements of every industry. The requirements from a large multi-national corporation are likely different to those from a small few-person company, and similarly the needs of say the semiconductor industry are likely different to those from the petroleum refining industry. There are also long-term and short-term research needs, with different demands on beamtime and involvement from support staff. Thus, we propose that any framework for moving forward to attract and support industrial researchers at NSLS-II incorporates flexibility and versatility.

Secondly, we strongly believe that the best model for industrial involvement to date is one where there is a stakeholder relationship between the facility and the company. This has been the foundation of the PRT/CAT or PUP model, and it has proven to be successful with mutual benefit to all involved. This concept should be given serious consideration for any plan moving forward.

The issues deemed critical to industrial users in the discussions of this working group mirrored those previously discussed in the BESAC SciTech report, and are summarized here (Appendix 1):

- Timeliness
- Quality
- Reliable and reproducible
- Expertise
- May not be familiar with the synchrotron technique
- Problem Focus
- Suite of tools
- Samples
- Many, real
- Geographic Access
- Travel budgets
- Compatibility
- ASTM/ISO methods
- Publishing

As a result it is recommended that the following are necessary components of any policy to attract researchers from industry to use a facility like NSLS-II:

- Develop an industrial access policy
- Develop access models for industrial users
- Develop workhorse capabilities
- Establish advisory committees
- Examine new models for IP protection
- Improve the cost model (more flexibility)
- Improve access requirements
- Establish incentives/different performance review metrics for staff members who support industrial users

See appendix 1

Industry Users' Consortium

The major outcome from our working group is the proposal to establish an Industry Users' Consortium (IUC), based upon the successful model of consortia that have previously been established e.g. Synchrotron Catalysis Consortium, COMPRES, CARS, etc. While there are many details that need to be determined regarding the establishment of such an IUC, we discuss here some fundamental concepts and suggestions. This white paper is not the place to specify the specific details of the IUC, as clearly this concept would need to be developed further via additional discussions and workshops.

We propose the formation of an industry users' consortium (IUC) at NSLS-II to allow members of the consortium to access appropriate beamlines for their R&D. The consortium would be open to all companies headquartered in the US. Each member company would pay a membership fee, and the amount paid would basically determine the amount of beamtime that each company is allocated. There are many different models that could be used for the fee structure, and this is a detail that needs to be discussed further. For example, one suggestion is that there would be a discounted fee for those members that were willing to commit to a multi-year agreement, as this would provide some financial stability to the consortium. Similarly, if a member required rapid access to a beamline, then there could be a premium added to their access fee.

One of the overarching themes that we propose is that many aspects of the IUC should allow for flexibility within some broad guidelines. There is no single "industry", and we would like to try to accommodate as many different types of user as possible, from a large group from a multi-billion dollar corporation to a one-man consulting company, and all companies in-between.

A certain fraction of beamtime at a suite of beamlines at NSLS-II would be made available to the IUC, with the maximum amount capped at a pre-determined level. This beamtime is taken from the top, before general user allocation. Initially this suite of beamlines would include X-ray absorption spectroscopy, x-ray diffraction, PDF, SAXS, and imaging – all broadly defined. There should also be a mechanism in place for access to more specialized higher-performance beamlines. Again, these details need to be flushed out.

It is not always intuitive to the industrial researcher whether a specific synchrotron-based characterization method will provide the necessary information to address the particular problem that they have. This is likely especially true for industrial researchers who have never used a synchrotron. As such there should be a mechanism whereby an industrial researcher could send a limited number of samples to the staff of the IUC for feasibility experiments. These data would then provide a mechanism for the industrial researcher to decide if they wish to join the consortium. There would be no fee for this feasibility study, and these studies should be integrated into the operation of the consortium as it would provide a path to potential new members.

The membership fee would subsidize the hiring of a dedicated group of staff members whose primary function will be to assist members of the consortium with their work. The head of this group would report directly to the Director of the Photon Sciences Directorate. The staff members would be available to assist the members of the IUC from planning experiments, to collecting the data, to analyzing and interpreting the data, as necessary. One idea suggested is that the members pay an extra hourly fee for staff services beyond a set amount for specialized advice and analysis. Attention also needs to be given to the terms of potential non-disclosure agreements that the company may want to execute with the facility industry support staff. It is possible that while the research itself is non-proprietary that some confidential information needs to be shared to ensure that the optimum experiment is conducted. Clearly, regarding job performance criteria, these staff members would need to be rated on distinctly different criteria than staff scientists at the beamlines. Once again these details need to be finalized.

The operation of the IUC would be overseen by an Industrial Advisory Board that reports to the Director of the Photon Sciences Directorate.

Each member of the consortium would need to provide metrics to document how their beamtime was utilized. At a minimum these metrics would include an annual impact statement, list of publications/presentations, and other supporting information.

While the Industry Workshop provided some insight into similar Industry programs at other facilities we suggest that more time and attention is paid to determining the best practices from other facilities operating industry programs in the US and abroad, and that these best practices are modified, as needed to suit the style of BES operated facilities, and incorporated into the operation of the IUC. We were particularly impressed with the way the industry program was set up at Diamond, together with the publicity and marketing materials that they have developed.

In summary, in the vast majority of cases the researcher from industry typically has a problem that needs a solution. As such they are typically interested in answers and not data per se.

Industry User Beamlines

There should be an evaluation of the development of highly automated beamlines with high sample throughput for some key workhorse characterization techniques e.g. XRD, XAFS, microtomography, high energy diffraction, that are much sought after for industrial research. These beamlines should have the capability for remote access from the home institution. These beamlines may, or may not currently exist in the suite of beamlines currently in the planning for NSLS-II. It is possible that such beamlines could be funded by sources not yet identified; for example, if industry is going to be the primary user then could the Department of Commerce, EERE, or an industry consortium, provide the capital required for the design and construction?

Appendix I

From Chapter 9 of Science for Energy Technology: Strengthening the Link between Basic Research and Industry (http://science.energy.gov/bes/news-and-resources/reports/)

"Industrial research needs" is a catch-all phrase that does not begin to capture the complexity of the needs of the industrial SUF community. It is understood that the demands of industrial research cover a wide spectrum: from a small company with a single research focus to a large global corporation with a diverse and large research portfolio; from a problem that requires an immediate answer due to a manufacturing or production issue to a long-term research problem; from a single sample to analyzing hundreds of samples; from a problem which involves a known technique to one where the analytical capabilities of a SUF need to be developed. Throughout this report, the reader is asked to keep in mind that there will not be a single solution to meet the needs of all industrial research at an SUF, but rather there must be flexibility and a range of possible solutions.

The suite of characterization tools, techniques, capabilities, and expertise available at the SUFs are unparalleled. As a result, US industry has been an active partner, stakeholder, and user of such facilities from the very earliest days of these BES facilities. Indeed, access to these facilities has become essential for the research and development operations of several corporations. Due to the cost and expertise required to design, construct, and operate such large facilities, it is unrealistic for an individual corporation to own and operate such a facility. This is especially true for the synchrotron radiation and neutron sources. In addition, few companies can consistently attract and maintain the large, scientifically diverse research staff such as those found at a SUF.

For the scientific information obtained at a SUF to have the desired impact on an industrial research program, there are some attributes that are required, and typically these are different from a comparable national laboratory or academia-led research program. These needs include the following:

- Timeliness - while there is variability in the length of a typical industrial research project, it is true that, on average, the lifetime of an industrial research effort is short (months to few years). For example, a technology delivery project will have milestones that have to be delivered monthly. Alternately, if there are issues with a manufacturing plant then the answer needs to be ideally delivered within a matter of hours or days. This necessitates that, in order for information from a SUF to have impact, there must be access to these facilities on a timely basis. Moreover, if particular tools/techniques have demonstrated benefit to a research project, access is needed on a regular basis to continuously add value, particularly for process development or reliability assessment.

- Quality - The data obtained at a SUF must be reliable and reproducible. This means that the equipment being used must be calibrated, be in good working order, and provide consistency in the data generated. Metrics must be kept and made available to demonstrate these points.

- Expertise - In order to be competitive, research in industry is usually conducted by multidisciplinary teams with the individual researcher having to engage in all aspects of the problem. Moreover, a typical researcher will be involved in multiple projects at one time, and often there is not continuity from one project to the next. These situations contribute to the fact that the industrial researcher may not have the expertise or the time to become an expert in a particular technique at a SUF, and the particular technique that is needed to solve the problem will vary with time. Significant mentoring throughout the whole period of interaction is likely required. This will be particularly true for smaller companies with few research staff.

- Problem-oriented - industrial research is typically problem-oriented. During the course of a research program, a particular problem may be encountered. The researcher needs to have the problem solved, not simply to have more data thrust at the problem. For complex problems, it is unlikely that a single technique at a single SUF will suffice. The researcher may need access to a suite of tools at several SUFs.

- Value - the research must ultimately solve the problem or provide answers to the question. Time is money and it is often the case that a particular researcher does not have the time or expertise to understand all the issues involved with conducting an experiment at a SUF, and thus different methods of engaging the researcher are required.

- Samples - To have the most effect in an industrial research program, the data should be obtained on the actual sample of interest, not a model or ideal sample. In addition, it is often the case that the data need to be obtained on many samples, comparing some physical or chemical property as a function of some process condition.

- Geographic Access - Travel budgets are under constant examination. During an economic slowdown, travel budgets are often the first to be cut. If the research at a SUF involves significant travel, it will be at risk. Industries will take geographic location of the facility into account when deciding at which SUF they will conduct their research.

- Compatibility - These are certain methods and procedures used by industry to ensure quality and compatibility. These include ASTM and ISO methods. It would be advantageous if data obtained at an SUF adhered to some of these methods and practices.

- Publishing - It is often the case that the results of industrial research are not published in the open literature. The research conducted by industry at a SUF may be deemed of clear interest to the company but not original enough to publish in the open literature.

- Confidentiality - Corporations make money by protecting their intellectual property. If the research is proprietary, then every effort should be made to ensure that the data collected at the SUF are protected. Even if the research conducted at a SUF is non-proprietary, there is an expectation that there is a degree of confidentially to the research.

Recommendation 1: Enhance industrial outreach by SUFs and develop a systematic and sustained effort to engage targeted industrial sectors

- Expand current SUFs outreach activities.

This would include establishing a specific website at each SUF targeted towards industrial users, attendance at targeted industry-sector specific conferences, production of brochures, and other outreach activities.

- Develop targeted, business-oriented, marketing to engage industry.

Promote networking among the SUFs to jointly achieve complete market coverage for industrial energy research.

- Identify needs of targeted industrial sectors by engaging industry and all SUFs.

Consider holding periodic 1-2 day workshops where a group of researchers from the SUFs target an industrial sector; for example, solid state lighting or advanced nuclear. Each workshop would highlight specific capabilities of SUFs focused on the specific needs of that research community. It would be highly interactive, informative, and problem-oriented. The goal would be to develop active, team-oriented collaborations.

- Develop industrial consortia to access SUFs.

These consortia would be facilitated by one or more of the SUFs and act as a resource of information and know-how for industrial problem-solving.

- Coordinate activities across all SUFs.

Ideally the activities would be coordinated across all of the SUFs to avoid unnecessary and potentially costly duplication of effort. While it is acknowledged that there is competition between the SUFs it is envisioned that a single SUF may not be able to act as a one-stop shop to solve an industrial research problem and thus will require access across multiple SUFs. Given the different procedures at each SUF mean there is the potential for a wide variability in how these recommendations may be implemented. Most issues are complicated by differences in SUF policies and procedures, such as meeting industry science needs, gaining access to facility time, and publishing results. A uniform approach for all SUFs is needed, coordinated by BES.

*The Joint Photon Science Institute at BNL/Stony Brook University is a potential model of an industrial research partnership. (see sidebar on JPSI).

Recommendation 2: Review and modify existing SUF user access policy and priorities to meet industrial research needs and to encourage and foster usage, and review and modify DOE policies to provide incentive for both industry and SUFs to develop a mutually engaging relationship

- Develop Industrial Access Policy

Each SUF is encouraged to develop an Industrial Access Policy that is comprised of the following:

– Each SUF director should be encouraged to set aside a fixed percentage (e.g. 10% is suggested; a modest increase from the current ~6%, and restoring the percentage from a decade ago) of specific capabilities at their facility for industry. Specific details of how this time is allocated should be up to the discretion of the facility director.

– The criteria that are used to evaluate a research proposals submitted by industrial users should be different from those from academia, and targeted towards technological excellence and impact rather than only scientific merit. An example of such criteria for evaluating proposals taking into account technological relevance or scientific relevance is given in the Appendix. The aim of this recommendation is to give equal weight to both technological and scientific criteria.

– Dedicated proposal review panels with membership including industrial peers should be established to rate these proposal.

– The use of rapid access time is encouraged in order to provide quicker turn-around time.

– Avenues should be explored to provide continued and regular access to the facilities for those industrial partners who have the need to engage in extended and sustained research at the SUF.

– The SUFs are encouraged to at least hire a full-time industrial liaison or develop a service-oriented group. This person would act as the first point of contact between the industrial user and the SUF and would strengthen, enhance, and coordinate the industrial research. The liaison would speak the language of an industrial researcher and be aware the task is to solve the problem at hand.

– The SUFs should explore providing services above and beyond those that they currently offer. Such enhanced services could include consultation services where they aid the industrial researcher to identify the best technique for their problem, aid in writing a proposal for access to the SUF, staff to work closely with the researcher in experiment planning, data collection, and data interpretation.

– Allocate funds so that SUFs could provide free first-time analyses for straightforward industrial research problems.

• Develop Access Models

Continue the range of access models to allow industrial users guaranteed access to facilities at the SUFs.

There is a track record of success of companies partnering as stakeholders in the development and operation of beamlines at synchrotron radiation sources leading to discovery and innovation. For example, the contributing/partner user model is highly successful and should continue.

• Develop Workhorse Capabilities

Establish a suite of optimized, state-of-the-art, fully-supported, techniques at the SUFs with remote access capabilities.

It is anticipated that there will be several techniques that will be in high demand for the vast majority of industrial research in the energy sector. These techniques (e.g. XRD, EXAFS, photoemission, SAXS) have become workhorse techniques in the existing industrial user community. Funds should be allocated to establish a suite of such capabilities that are state-of-the-art, fully staffed, with high-throughput capabilities, and remotely accessible. The prioritization of these capabilities could be facilitated using industrial program advisory committee with guidance from user statistics to validate the choice of beamline suite.

• Establish Advisory Committees

– Each SUF should strive to include at least one researcher from industry on their Scientific Advisory Committee.

– Each user organization at each SUF should include at least one member from industry.

– An industrial program advisory committee should be established at each SUF where an enhanced industrial access program is established.

• IP issues

– New models for IP protection for engaging with US industry should be examined.

The IP complexity of academia/national laboratories working with industry is not new, and detailed recommendations are outside the scope of this report. It is clear that more flexibility and simplification of DOE policies regarding IP issues is needed to better build industrial usage of SUFs. The IP issue is complex and requires further study by qualified individuals.

- Costs

– The current full-cost recovery requirement should be studied in more detail.

The current model of calculating full-cost recovery for proprietary time at SUFs, a "one-fee covers all" approach, could be more flexible by using a graded cost structure based on the capability of the experimental equipment and/or fee per sample/analysis. Again, the details are outside the scope of this panel but this is a critically important area and needs to be revisited.

- Uniformity

– Every measure possible should be made to ensure that there is uniformity in the requirements for an industrial researcher to access an SUF.

There is a perceived barrier to initiate an industrial research program at an SUF due to the overwhelming administrative burden. These burdens include the fact that each SUF has different requirements for access, safety, proposals, training, and badging, to name a few. Training and safety related issues could be easiest to target as there is uniformity in these aspects

- Incentives

There should be incentives and recognition established to encourage SUF management and staff at the SUFs to interact and collaborate with industrial users.

Appendix II

INDUSTRIAL RESEARCH AT NSLS–II

Workshop Agenda

April 8-9, 2014
NSLS-II, Brookhaven National Laboratory, Upton, New York
Location: Berkner Hall, Conference Room B

8:00	Continental Breakfast	
8:30	Welcome and BNL Perspective	Doon Gibbs (BNL Lab Director)
8:45	Welcome and NSLS-II Overview	Steve Dierker (Associate Lab Director for Photon Science)
9:10	Scientific Programs Planning and User Access	Qun Shen (Deputy Director for Science, Photon Sciences Directorate)
9:35	Beamline Capabilities Ramp-up at NSLS-II	Paul Zschack (Photon Division Director, Photon Sciences Directorate)
10:00	Coffee break	
10:30	"Connecting Research Infrastructure with Industry: The Adventures of the ESRF"	Edward Mitchell (Manager, Industry Program at ESRF)
10:50	"The Industrial Diamond"	Elizabeth Shotton (Manager, Industry Program at Diamond)
11:10	"Canadian Light Source LESSONS LEARNED: How to GET Industry TO Play in the Sandbox"	Jeffrey Cutler (Director, Industrial Science)
11:30	Industry Program at the NSLS - Current Status	Jun Wang (Manager Industry Program, Photon Sciences Directorate)
11:50	Lunch	
1:00	Partnering with BNL	Mike Furey (Research Partnerships Manager, BNL)
1:30	"25 Years of Industrial Research at User Facilities: Thoughts and Insights"	Simon Bare, UOP, A Honeywell Company
1:50	"Industrial Use of National Facilities – "GE's Experience and Perspective"	Yan Gao (General Electric)
2:10	"Industry - University Partnerships at a DOE Facility: One Academic's View"	Peter Stephens (Stony Brook University)
2:30	Break	
3:00	"Pharmaceutical Macromolecular Crystallography at Synchrotrons"	Steve Sheriff (Bristol Myers Squibb)
3:20	"Beamline – an Useful & Must Have (?) Tool for Industrial Material Science Development"	Ying Shi (Corning)
3:40	"Cutting Through the Complexity of Crude with an X-ray Light Saber"	Kyle Litz (Auterra. Inc.)
4:00	"Industry/University Cooperative X-ray Topography Research at a DOE Synchrotron	Michael Dudley (Stony Brook University)

	Light Source"	
4:30	NSLS-II Tour	Tour Leaders
6:00	Networking Dinner - Sponsored by Photon Sciences Users' Executive Committee	

April 9, 2014

8:30	Bagel Breakfast Breakout sessions: small working groups organized by types of industry to discuss industry needs, structure of support, ways of participating, etc.	Facilitators: Sean McSweeney – Pharmaceuticals Simon Bare – Catalysis/ Petrochemicals Eugene Lavely – Microelectronics Alex Norman - Polymers Stan Petrash – Advanced Materials
10:40	Break	
11:00	Reports from Break-Out Sessions	Facilitators
12:00	Path Forward	Jun Wang (Manager Industry Program, Photon Sciences Directorate)
12:15	Adjourn	

*** Registration for this workshop includes: Breakfast, Coffee Breaks, Lunch, and the Networking Dinner**

Appendix III

Participant List

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