From:	Baker, Robert
To:	Smith, Randy; Leite, Fabio
Cc:	Reed, Katie; Carnes, Cynthia; Spellacy, Amy; Mohler, Peter
Subject:	NeXUS University Center Proposal
Date:	Tuesday, February 20, 2024 3:59:59 PM
Attachments:	image001.png NeXUS University Center Proposal_Compiled.pdf

Dear Dr. Smith and Dr. Leite,

Thank you for your assistance obtaining provisional center status for the National eXtreme Ultrafast Science facility (NeXUS) this past summer. Since then, things have progressed rapidly, and we have submitted a proposal for 5 years of Operation and Maintenance funding to NSF. We are currently preparing for an NSF site visit on April 23-24 to evaluate this proposal.

I am writing to submit the application for full University Center Status for NeXUS (see attached). This proposal has been prepared in coordination with ERIK, who strongly supports the application. This proposal also includes letters of support from various additional academic units and university centers and institutes.

Please let me know if additional information is needed, and I would be glad to discuss any questions.

Best regards,
Robert

L. Robert Baker
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Department of Chemistry and Biochemistry
Director, NSF NEXUS
John Von Neumann Distinguished Fulbright Fellow

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The Ohio State University

National eXtreme Ultrafast Science Facility (NeXUS)
University Center Proposal

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National eXtreme Ultrafast Science Facility (NeXUS)

University Center Proposal

I. Mission

Overview and Vision

NeXUS is a first-of-its kind ultrafast laser facility in the US. Until recently, research in ultrafast, high-intensity laser science in the US has lagged behind strategic investments in Europe and Asia as documented by the 2018 National Academy of Science report, "Reaching for the Brightest Light." [National Academies of Sciences. 2018. *Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light.* Washington, DC: The National Academies Press. https://doi.org/10.17226/24939.] However, this situation is now changing rapidly thanks to significant recent federal investments in ultrafast science, such as the NSF Mid-Scale Research Infrastructure (MSRI) program. The NeXUS facility was established at The Ohio State University in 2019 as one of the inaugural MSRI awards and is currently supported by a $10.5M infrastructure grant. The NeXUS project translates new technology in high average power lasers developed in Europe to the US for the first time. This technology provides a combination of attosecond pulses, XUV and soft x-ray photon energies, and high repetition rates that will enable ultrafast measurements in molecules and materials that currently cannot be made anywhere else in the US. Accordingly, NeXUS is designed to fill a strategic gap in the US research infrastructure. The unique capabilities and international visibility of this facility are establishing The Ohio State University as a global leader in ultrafast science.

By NSF mandate, this investment is intended to create a Gateway facility through which the entire research community can access these unique-in-the-US research capabilities. To fulfill this mission, NSF invited the submission of a second proposal to support 5 years of Operations and Maintenance (O&M) of the NeXUS facility. This O&M proposal was submitted by the NeXUS team in November 2023, and is currently under evaluation by NSF. This proposal requests a $12M total budget (including $4M in F&A) to support an open access, national user program at NeXUS. The start date for this 5-year project is July 2024. Based on continuing support from NSF, we anticipate that NeXUS will continue to grow to meet the rapidly evolving needs of the ultrafast research community. Accordingly, this facility forms the basis for a long-term, synergistic partnership between NSF and OSU.

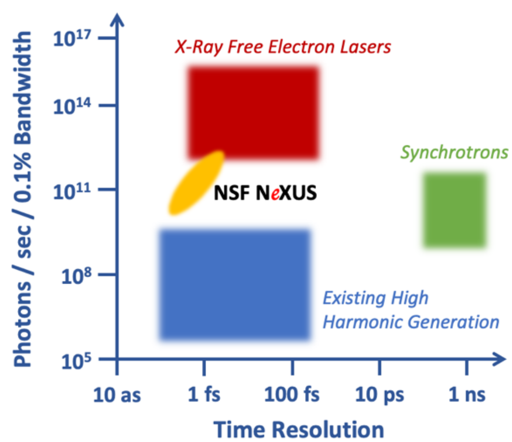

Figure 1. *Photon flux and accessible time resolution for existing XUV and x-ray sources compared with the NeXUS facility. NeXUS bridges the gap between tabletop sources and x-ray free electron lasers.*

NeXUS Mission and Justification for University Center

The NeXUS facility utilizes a high average power, kilowatt-class laser to generate XUV and soft x-ray light. This light is then delivered to a suite of beamlines and end-stations, enabling a breadth of cross-cutting science spanning multiple disciplines in science and engineering. In essence, the mid-scale NeXUS facility is bridging the national research gap between tabletop light sources and large-scale facilities, e.g., x-ray free electron lasers (see Figure 1), and is designed to provide a flexible, accessible, and economical solution to meet the needs of a growing scientific community.

Not only will NeXUS bridge a current gap in the US research infrastructure, but as an open access user facility, the NeXUS facility will also create a new paradigm for nation-wide scientific impact. Thanks to its unique intersection of a high average power, ultrafast XUV light; suite of molecular and materials characterization end stations; highly trained research scientists, technical, and administrative support staff; and engaged participation by users, NeXUS will represent a complete scientific ecosystem (Figure 2). The goal of NeXUS O&M is to create both a facility and culture where scientific discoveries are accelerated. Successful NeXUS O&M will enable a diverse community of users to advance US competitiveness in fields ranging from energy conversion and catalysis to quantum material dynamics to ultrafast biology.

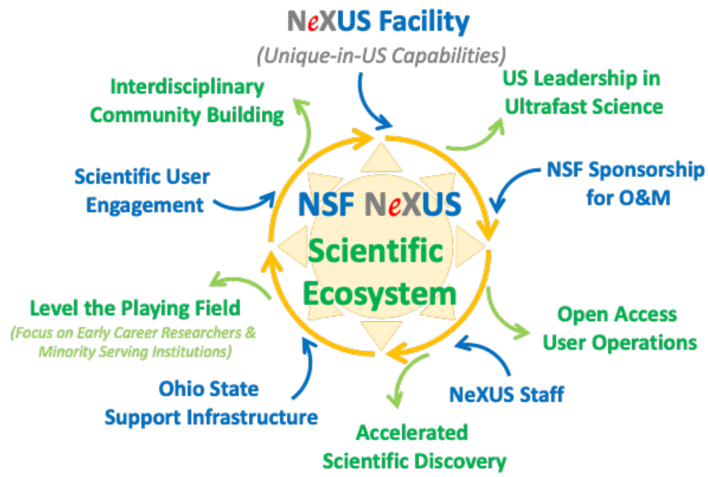

Figure 2. *The goal of NeXUS O&M is to create a scientific ecosystem that will shape the future of ultrafast science. Blue arrows represent key elements required to create and sustain this ecosystem, and green arrows represent direct benefits of this ecosystem to the scientific community and society.*

To highlight the enthusiastic response to NeXUS by the research community, to date NeXUS has hosted two user's workshops, which were attended by more than 200 individuals from 75 institutions and 13 countries. To provide an overview of the diverse scientific fields supported by NeXUS, these workshop participants receive support from the following NSF divisions:

- Division of Chemistry
- Division of Physics
- Division of Materials Research
- Division of Molecular and Cellular Biosciences
- Division of Electrical, Communications, and Cyber Systems
- Division of Civil, Mechanical, and Manufacturing Innovation
- Division of Chemical, Bioengineering, and Transport Systems

As evidenced by this enthusiastic community-wide response to NeXUS, the promised impact of this facility will soon be realized through its open-access user program beginning in 2024.

The mission of NeXUS is inherently multidisciplinary and transcends the boundaries of traditional academic units. NeXUS has an obligation to serve the broader user community by providing access to unique-in-the-nation capabilities in ultrafast science regardless of the user's institution or scientific discipline. To protect this unique mission, it is important to ensure that NeXUS oversight does not fall under the domain of a single OSU academic unit or center. Designation of NeXUS as an independent Ohio State University center is necessary to 1) enable

NeXUS to fulfill its unique mission that transcends traditional academic boundaries, 2) demonstrate to NSF a strong level of internal OSU support for this facility, which will be necessary to secure funding for long-term facility O&M, and 3) provide direct communication between the NeXUS Director, External Advisory Board, Internal Oversight Committee, and ERIK for successful management and oversight of this interdisciplinary facility.

Accordingly, this proposal outlines a vision for NeXUS as an Ohio State University Center under ERIK that will ensure the long-term success of this OSU/NSF partnership and maximize the community-wide impact of this facility. Of key importance is the ability to support and manage a national open-access user program that will provide researchers from a range of institutions and diverse fields access to state-of-the-art characterization tools for studying ultrafast dynamics in molecules and materials. The net result of this University Center will be to establish Ohio State as a national and international leader and focal point of multidisciplinary collaboration in ultrafast science.

II. Faculty

Criteria for Faculty Participation

The NeXUS facility will operate as an open access user facility. Under this model, researchers will propose experiments through a competitive, peer-reviewed process, and selected applicants will be awarded facility time. Per NSF mandate, NeXUS must maintain a transparent external peer-review process to ensure equitable access based on scientific merit to all users regardless of institutional affiliation. As described in Section III below, an external User Committee will be formed to represent the interests of the scientific user community, and this committee will report regularly to NSF and OSU leadership on the degree to which NeXUS successfully fulfills this mandate.

NeXUS Impact on Ohio State Faculty

This model of user engagement will also enhance the research efforts of OSU faculty and staff through 1) ready access to state-of-the-art capabilities in ultrafast molecular and materials characterization, 2) interaction and collaboration with leading research groups worldwide who will visit OSU campus as NeXUS users, and 3) strategic overlap between NeXUS capabilities and existing interdisciplinary research centers at OSU. Any Ohio State faculty member or research associate is eligible to submit a proposal to become a NeXUS user.

To demonstrate the multidisciplinary impact of NeXUS across The Ohio State University, the following colleges and departments have committed to provide cost share to support NeXUS O&M (see attached MOU): College of Arts and Sciences, College of Engineering, Department of Chemistry and Biochemistry, Department of Physics, Department of Chemical and Biomolecular Engineering, Department of Materials Science and Engineering, and Department of Electrical and Computer Engineering. NeXUS will also enhance the missions of various university centers and institutes, including the Institute for Optical Science (IOS), Institute for Materials and Manufacturing Research (IMR), Center for Quantum Information Science and Engineering (QISE), Center for Emergent Materials (CEM), Center for Design Manufacturing and Excellence (CDME), and OSU Sustainability Institute (SI).

Two recent examples demonstrate how NeXUS is already promoting research excellence at Ohio State: 1) Former Director of the Center for Emergent Materials, Prof. Chris Hammel, reported that the recent successful renewal of this NSF MRSEC at OSU ($18M) benefited greatly from the unique capabilities expected to become available to OSU researchers through access to the NeXUS facility. 2) NSF recently launched an AccelNet design project, Extreme Light in Intensity, Time, and Space (X-lites). X-lites is led by Ohio State through the Institute for Optical Science and supports the creation of an international network of networks, which connects NeXUS to 9 other leading laser research centers worldwide (3 in the US and 6 in Europe). Another proposal to support four years of international networking activities is currently under review by NSF. The visibility and leadership of OSU in coalescing the international light source community around these new facility investments is uniquely enabled by the location of NeXUS on Ohio State campus. As NeXUS transitions from the facility development stage into open access user operations beginning in 2024, the far-reaching impact of this facility on OSU researchers will continue to grow.

Faculty Participants

Table 1 provides a list of OSU faculty who expressed enthusiasm for the creation of the NeXUS facility and who are likely to become future users of this facility. Associated letters of support from the respective department chairs and college deans are included below in Section VI.

Table 1. *OSU faculty likely to become future users/collaborators of the NeXUS facility.*

OSU Faculty Member	Research Area
Rolando Valdes Aguilar	Quantum Materials
Enam Chowdhury	Ultrafast Microscopy
Joshua Goldberger	Quantum Materials
Kay Halasek	Teaching and Outreach
Ezekiel Johnston-Halperin	Quantum Materials
Jinwoo Hwang	Ultrafast Magnetism
Alexandra Landsman	Attosecond Dynamics
Yuan-Ming Lu	Topological Materials
Roberto Myers	Quantum Materials
Mohit Randeria	Ultrafast Magnetism
Fengyuan Yang	Ultrafast Magnetism

Staff and Student Participation

During the development project, the NeXUS project has supported a total of 8 graduate students, 9 postdocs, 5 research scientists, and 2 administrative assistants. As the NeXUS facility transitions from the development phase to O&M, graduate students and postdocs will be replaced by a group of full-time professional staff, including research scientists, technical support staff, and administrative staff. This is required to provide the necessary support for external users to visit OSU and conduct independently proposed experiments as well as to support the maintenance and operation of the facility, which is outside the scope of graduate student and postdoctoral research. However, Ohio State graduate students and postdocs will continue to play an active role as future users of NeXUS, where the unique capabilities will enhance their research, promote the international visibility of their work, and provide opportunities in workforce training and education that cannot be gained at any other US institution. Table 2 shows the number of full-time professional staff that will support NeXUS during the first 5 years of O&M beginning in 2024 as requested in the NSF O&M proposal.

Table 2. NeXUS staffing during first 5 years of O&M.

Project Fiscal Year	2024	2025	2026	2027	2028
# Administrative Staff	2	2	3	3	3
# Research Scientists	3	4	4	4	4
# Technicians	2	3	3	4	4
# Total Staff	7	9	10	11	11

III. Administration

NeXUS Internal Administration

The internal administrative structure of the NeXUS facility will consist of a Director, a Deputy Director, a Facility Manager, and an Internal Oversight Committee (IOC). The Principal Investigator of the NSF-sponsored project (Robert Baker) will serve as the Facility Director. At the discretion of the Director, one of the co-principal investigators will serve as Deputy Director. Louis DiMauro will serve as the first Deputy Director. Per NSF guidance, the Office of Research should oversee administration of NeXUS operations independently from any other academic unit or university institute. Accordingly, the NeXUS Director will report directly to the Vice President for Research (Peter Mohler) and to the Senior Associate Vice President for Research Operations (Cynthia Carnes).

A Facility Manager will be responsible for administering the NeXUS facility. The Manager will supervise facility staff and take responsibility for effective operation. The Manager will also evaluate the performance of the facility against its planned schedule and budget, prepare performance reports for the Director and other stakeholders, oversee the NeXUS user program, and schedule experiment time for selected users. TJ Ronningen is an OSU Research Scientist with more than 10 years of industry experience managing system development projects and has been named as the Facility Manager in the NSF O&M proposal.

To provide oversight to the NeXUS facility, an IOC will be appointed. The IOC will consist of OSU stake holders with broad representation from the various research fields supported by NeXUS. The IOC will advise the Director on all major activities and goals, will receive annual reports on NeXUS accomplishments, and will provide guidance and feedback to the Office of Research on the performance of the NeXUS facility. The Senior Associate Vice President for Research Operations will serve as chair of the IOC.

NeXUS External Administration

As an externally sponsored NSF user facility, additional sponsor-mandated administrative structure for NeXUS includes an External Advisory Board (EAB) and a User Committee (UC). The EAB consists of internationally recognized experts in various fields of science and education relevant to NeXUS missions. The membership of the EAB is appointed by the Director with approval of the cognizant NSF program officer. Table 3 lists the current membership of the EAB. The EAB plays a significant role in guiding the strategy of the facility to ensure it is providing value to the research community. The EAB will meet annually with the Director to review the facility status and activities, discuss plans (near term and long term), and provide feedback. The Director will support this annual meeting by providing the EAB with a written report in advance of the meeting. The EAB has authority to issue independent reports to the NSF and the Ohio State Office of Research on the performance of NeXUS.

Table 3. NeXUS External Advisory Board

Board Member	Institution	Expertise
Philip Bucksbaum (Chair)	Stanford University, SLAC	High Intensity Lasers Facility Management
David Awschalom	University of Chicago	Quantum Materials
Gregory Boebinger	Florida State University National High Magnetic Field Lab	Superconductivity Facility Management
Lin Chen	Northwestern University Argonne National Lab	Solar Photochemistry
Anthony Johnson	University of Maryland Center for Advanced Studies in Photonics Research	Material Photophysics Outreach & Education
Roseanne Sension	University of Michigan	Physical Chemistry
Linda Young *(ex officio)*	University of Chicago Argonne National Lab	Chemical Physics Facility Management

The role of the UC is to represent the needs of the scientific community and to provide feedback to the NSF on the operations of NeXUS from the perspective of the end user. To ensure an independent voice on behalf of the user community, the UC reports directly to the NSF with an additional line of communication to the Facility Director. The chair of the UC is appointed by the Director with approval of the cognizant NSF program officer. The chair of the UC will also serve as an ex officio member of the EAB. The UC will meet annually with the Director to provide feedback and advice on the operation of the facility. The UC will contact NeXUS users to solicit input and advice based on their experiences at NeXUS. The UC has the authority to issue independent reports to the NSF and Office of Research. The UC also has authority to establish its own bylaws and elect members, but employees of Ohio State are not eligible for UC membership. The UC will ensure a strong voice to early career faculty and researchers from primarily undergraduate and minority serving institutions. Prof. Linda Young (Distinguished Fellow at Argonne National Lab and Professor of Physics at University of Chicago) currently serves as chair of the UC.

Figure 3 shows an organizational chart based on this administrative structure for the NeXUS facility.

IV. Budget

Historical Context – Support for the Original NeXUS Development Project

The NeXUS development project began in 2019 as a $9.5M award from NSF for construction of the NeXUS facility. In 2022 and 2023 the NeXUS project received two separate project supplement awards from NSF for $487k and $498k, respectively, bringing the total award budget to $10.5M. OSU cost share has also been provided to support the original NeXUS development project. This includes support from Office of Research for renovation of the NeXUS laboratory as well as cash contributions from Office of Research ($250k), College of Arts and Sciences ($250k), College of Engineering ($100k), Department of Chemistry and Biochemistry ($125k), and Department of Physics ($125k). These funds have been used to support graduate student tuition awards, managerial and administrative staff salaries, meetings and travel, recruitment, and consumable supplies. This original NeXUS development project is scheduled to be completed in 2024, and plans to support the ongoing operations of the NeXUS facility are described below.

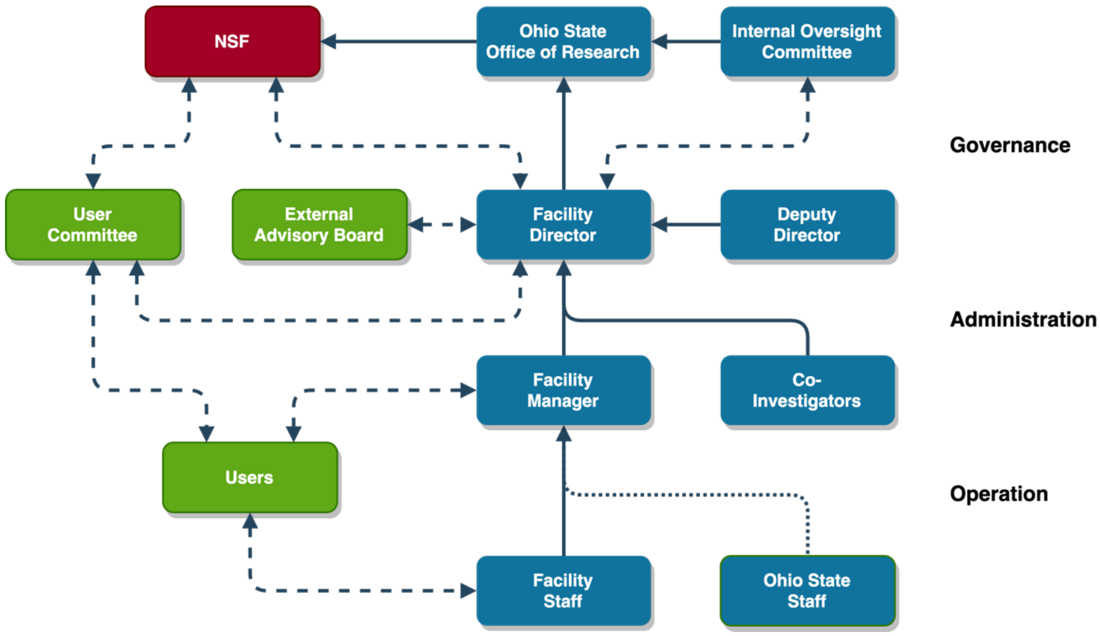

Figure 3. *NeXUS organization chart. Blue rectangles indicate Ohio State, red indicates sponsor and green indicates external. Solid lines are lines of direct reporting, dashed lines are lines of communication, and the dotted line is a line of indirect reporting.*

Support for NeXUS Operations & Maintenance

Funding for this NeXUS development project supports only the construction and commissioning of the NeXUS facility but does not include support for facility operations. To support NeXUS operations, a second proposal for 5-year O&M has been submitted to NSF and is currently under review by the Division of Chemistry. A site visit including NSF visitors and external reviewers will occur in Spring 2024 prior to an award decision. For reference, the NeXUS O&M proposal is attached here as Appendix I in Section VI.

Table 4 summarizes the 5-year project budget requested from NSF for NeXUS O&M. The primary expenses associated with NeXUS O&M are salaries to support NeXUS research scientists, technicians, and administrative support staff, service contracts for major equipment, capital expenses for facility upgrades, and consumables, supplies, and system maintenance required to operate an open access user program.

Table 4. 5-year project budget requested from NSF for NeXUS O&M.

Project Fiscal Year	**2024**	**2025**	**2026**	**2027**	**2028**
Personnel	$717,219	$1,085,066	$1,200,232	$1,240,425	$1,265,234
Equipment	$20,000	$20,000	$230,000	$136,480	$20,000
Participant Support	$8,000	$48,000	$48,000	$48,000	$48,000
Travel	$12,000	$15,000	$15,000	$15,000	$15,000
Materials/Supplies	$50,000	$80,000	$110,000	$130,000	$140,000
Service Contracts	$80,270	$162,375	$244,513	$249,403	$254,391
Hosted Meetings & Outreach	$5,000	$20,000	$20,000	$20,000	$20,000
F&A	$497,081	$783,404	$914,103	$951,526	$974,409
Total	**$1,389,569**	**$2,213,846**	**$2,781,848**	**$2,790,835**	**$2,737,035**

We anticipate that NSF will invite renewal proposals for continuation of NeXUS O&M every 5 years over the >20 year expected life span of the NeXUS facility. NSF has communicated a long-term vision that includes additional investments over time for expansion and growth of NeXUS. The National High Magnetic Field Laboratory (MagLab) is an NSF-sponsored facility that serves as an aspirational model for NeXUS. The MagLab moved to Florida State University in 1990 having a size and scope similar to NeXUS. As a result of continuing NSF and state investments, in 2022 the MagLab was supported by a $38.9M annual NSF operations budget, consisted of 7 distinct user facilities, hosted more than 1,950 users, and published more than 350 papers.

Requested University Support for NeXUS

While NeXUS O&M will be primarily supported by external funds from NSF, the success of NeXUS will also require support from The Ohio State University. This support will not only ensure success of the NeXUS facility, but it will also form the basis for a long-term partnership with NSF that will establish Ohio State as an international leader in ultrafast science. The requested support includes both cash and in-kind contributions to ensure successful facility operation, recruit and retain talented scientific and administrative support staff, and ensure sufficient administrative support for NeXUS leadership.

A 5-year cost share commitment to support NeXUS O&M has already been agreed to between ERIK and the following colleges and departments:

College of Arts and Sciences

- College of Engineering
- Department of Chemistry and Biochemistry
- Department of Physics
- Department of Chemical and Biomolecular Engineering
- Department of Electrical and Computer Engineering
- Department of Materials Science and Engineering

A signed MOU reflecting this commitment by the various contributing units is included below in Section VI. The university cost share committed by this MOU will be used to support the following project needs:

Director Support

- Faculty administrative attachment
- Director teaching release (1 semester / year)
- Administrative assistant (25% FTE)

NeXUS Staff Support

- Facility Manager (TJ Ronningen): 10% FTE
- NeXUS Research Scientists: 25% FTE each

Support for In-House Research

- Equipment, materials, and supplies for in-house NeXUS research. The purpose of these funds is to support in-house efforts by NeXUS research scientists with the goal to target future external funding opportunities, especially center-level funding, uniquely enabled by NeXUS capabilities.

In-Kind Support

- ACS Machine Shop – To support priority machining needs at NeXUS, one machinist at 50% FTE is required. (Committed by College of Arts and Science)
- ASC Tech – To support collection, storage, and transfer of large data files at NeXUS, one tech specialist at 25% FTE is required. (Committed by College of Arts and Science)
- CBC Instrument Group – To support instrumentation needs at NeXUS, one specialist at 25% FTE is required. (Committed by Department of Chemistry and Biochemistry)
- User Office Space – NSF requires onsite office space for a team of 8 external users during experiments at NeXUS (duration 1-3 weeks). (Committed by Department of Chemistry and Biochemistry)
- Staff Office Space – Space is required for approximately 12 full time NeXUS staff, including a facility manager, 4 research scientists, 4 technicians, and 2 administrative assistants. (Committed by Department of Chemistry and Biochemistry)

Future NeXUS Space Considerations

The NeXUS facility is currently housed in Celeste Laboratory within the Department of Chemistry and Biochemistry. However, space constraints in Chemistry and Biochemistry preclude any future NeXUS expansion, despite the high probability of continuing NSF investment in this facility. Consequently, we strongly recommend planning for future NeXUS expansion into the Carmenton innovation district.

V. Evaluative Criteria and Benchmarks

Criteria for evaluating the NeXUS facility should be based on the success of NeXUS goals and benchmarks in the following areas:

1. Successful completion of the NSF-funded NeXUS development project (2024).
2. Acquisition of NSF funding to support 5 years of NeXUS O&M (2024).
3. Continuous assessment of the impact of NeXUS on
   a. Scientific discovery enabled by this unique-in-the-US research infrastructure.
   b. International leadership and visibility of The Ohio State University in ultrafast science.

The NeXUS development project is scheduled to end in December 2024. To transition from facility development to O&M, a number of key milestones must be met in 2024:

1. Integration of the NeXUS laser with the three custom beamlines to verify the generation of XUV light in each of them.
2. Verification testing of two custom end stations using the NeXUS laser and beamlines.
3. Assembly and verification of two add-on components to support analysis of liquid and magnetic samples.
4. Validation/commissioning experiments that demonstrate the experimental capabilities of NeXUS beamline + end station combination.

5. Hosting the third NeXUS user workshop to share the operational plans and prepare users for the first call for experiments.

NeXUS will also be evaluated based on the acquisition of NSF funding to support operation of the facility as a national open access user facility. A proposal for NeXUS O&M has been submitted to NSF in November 2023 and is currently under evaluation. In the coming months the following activities will be required to successfully compete for this award and to transition the facility from the current development stage to O&M:

1. Host a NeXUS site visit from an external committee composed of NSF leadership and external experts. This site visit is being organized by the NSF cognizant program officer and is planned for April 25-26, 2024.
2. Host a NeXUS user workshop to advertise NeXUS capabilities and solicit the first round of user proposals. This workshop is expected to attract broad national and international participation and is planned for July 23-24, 2024.
3. Open the first call for NeXUS user proposals. This will require the NeXUS team to:
    a. Define specific set of first experiments designed to showcase NeXUS capabilities.
    b. Assemble an external proposal review panel composed of scientific experts.
    c. Invite proposal submissions.
    d. Coordinate safety, feasibility, and merit reviews of proposals received.
    e. Allocate NeXUS instrument time based on the results of the review process.
    f. Initiate interactions between NeXUS staff and users to plan and conduct experiments.

Successful operation of NeXUS promises to establish The Ohio State University as a national and international leader in ultrafast science. As such, this facility will attract users from around the world, making Ohio State a focal point of multidisciplinary collaborations enabled by advanced characterization of molecules and materials. To determine the success of this university center, NeXUS will be regularly evaluated based on the impact of its open access user program on the scientific community as well as the impact of this facility on the international leadership and visibility of The Ohio State University. The following metrics will be used to annually evaluate NeXUS performance:

1. Facility metrics, including:
    a. Percent facility time dedicated to external users.
       (Target: 50% in Year 1, increasing to 65% by Year 3)
    b. Active data hours reflecting time spent supporting users.
       (Target: 630 in Year 1, increasing to 1,500 by Year 3)
    c. Number and demographics of NeXUS users.
    d. List of publications acknowledging NeXUS support.
2. Written reports from the following committees
    a. NeXUS External Advisory Board
    b. NeXUS User Committee
    c. NSF Site Review Panels (anticipate annual site visit reports from NSF)

Based on these reports and metrics, the Director will prepare an annual report evaluating performance and accomplishments in the above areas and highlighting goals and objectives for the coming year that will be shared with the OSU Office of Research. Additionally, the Office of Research may request evaluation of NeXUS by the IOC to better understand the performance and impact of NeXUS from the perspective of its various OSU stake holders.

VI. Supporting Materials

1. Appendix I: NSF Proposal for NeXUS Operation & Maintenance
2. Appendix II: Signed MOU for NeXUS University Cost Share
3. Appendix III: Letters of Support
    a. Peter Mohler, Executive Vice President for Research Innovation and Knowledge
    b. Nate Ames, Executive Director, Center for Design and Manufacturing Excellence
    c. Kate Bartter (Executive Director) and Elana Irwin (Faculty Director), Sustainability Institute
    d. Louis DiMauro, Director, Institute for Optical Science
    e. Joshua Goldberger, Director, Center for Emergent Materials
    f. Christopher Jaroniec, Associate Dean for Research, College of Arts and Sciences
    g. Ezekiel Johnston-Halperin and Ronald Reano, Co-Directors, Center for Quantum Information Science and Engineering
    h. Michael Mills, Department Chair, Materials Science and Engineering
    i. Umit Ozkan, Department Chair, Chemical and Biomolecular Engineering
    j. Michael Poirier, Department Chair, Physics
    k. Steven Ringel, Executive Director, Institute for Materials and Manufacturing Research
    l. Balasubramaniam Shanker, Department Chair, Electrical and Computer Engineering
    m. Claudia Turro, Department Chair, Chemistry and Biochemistry
    n. Seth Weinberg, Associate Dean for Research, College of Engineering

1. Introduction

1.1. Background and Motivation

In 2019 the National Science Foundation (NSF) funded the National eXtreme Ultrafast Science (NeXUS) facility development. This investment promises to have a transformative effect on chemistry, physics, biology, and materials science. The need to control energy and information transport at the scale of individual atoms and electrons is required to enable new technologies for solar energy conversion and quantum information processing. However, these goals can never be realized without the ability to directly observe the underlying dynamics on the relevant scales of time and space. This calls for putting techniques capable of attosecond to femtosecond time resolution, angstrom spatial resolution, and element-specific spectral resolution directly into the hands of the scientific community.

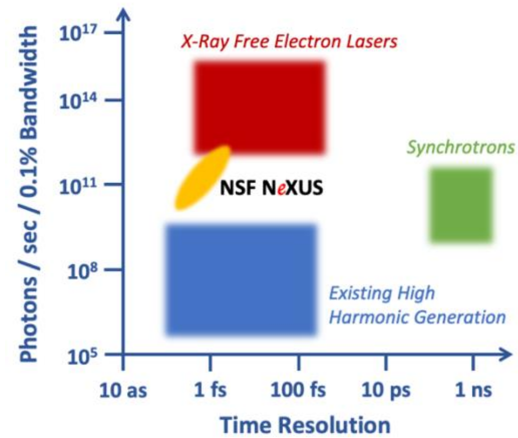

Figure 1. Photon flux and accessible time resolution for existing XUV and x-ray sources compared with the NeXUS facility. NeXUS bridges the gap between tabletop sources and x-ray free electron lasers.

The NSF's infrastructure investment in NeXUS responds to this challenge by transforming the research landscape in the United States (US), providing broad user access to cutting-edge ultrafast extreme ultraviolet (XUV) technology. This NSF investment is poised to significantly strengthen US competitiveness on the international stage. Until recently, research in ultrafast, high-intensity laser science in the US has lagged internationally due to strategic investments in Europe and Asia. However, this situation is now changing rapidly thanks to federal investments like NeXUS. NeXUS translates newly developed, high average power laser technology into high flux XUV/soft x-ray ultrafast sources. The light is delivered to a suite of beamlines and end stations, enabling a breadth of cross-cutting science. In essence, the mid-scale NeXUS Facility is bridging the gap between tabletop light sources and large-scale facilities, such as x-ray free electron lasers (see Figure 1).

This proposal outlines a vision for NeXUS Operation & Maintenance (O&M) that will ensure the success of this NSF investment by maximizing the community-wide impact of the NeXUS facility. During O&M, NeXUS will link together its cutting-edge light sources, state-of-the-art analysis end stations, and professional staff with a diverse community of scientific researchers. This combination of elements will enable NeXUS to support a dynamic, open-access user program that will level the playing field by providing researchers from a range of institutions and fields access to the most advanced characterization tools available worldwide for studying ultrafast dynamics in molecules and materials.

1.2. Overview of the NeXUS Facility

The NeXUS system was designed and constructed to enable direct observation of electron motion with attosecond to femtosecond time resolution, angstrom spatial resolution, and element-specific spectral resolution. At the heart of the system is a kW-class ultrafast laser that produces XUV and soft x-ray light by high harmonic generation (HHG) at 100 kHz to 5 MHz repetition rates. The combination of attosecond pulses, soft x-ray photon energies, and high repetition rate will enable measurements that currently can only be made at a handful of places worldwide. XUV light is coupled to one of three different beamlines for creation of custom pulses with bandwidth and durations tailored for various experiments. Photon budgets, spectral range, bandwidths, and pulse durations available from each beamline are shown in Figure 2. The beamlines deliver these tailored pulses to one of four end stations for experiments:

- **Time-Resolved X-Ray Absorption/Reflection Spectroscopy (TR-XAS/XRS) –** This end station enables x-ray absorption spectroscopy of molecules and materials with attosecond to femtosecond time resolution. Applying this to solution phase and interfacial systems will provide understanding and control of charge and spin transport during solar energy conversion, heterogeneous catalysis, and spin crossover in molecular magnets. This end station also includes two add-on capabilities: First is the ability to generate thin liquid sheets for ultrafast studies of molecules in solution. Second is a broadband circular polarizer to support x-ray magnetic circular dichroism (XMCD).

- **Time-Resolved Scanning Tunneling Microscopy (TR-STM) –** This end station couples tunable, monochromatic, soft x-ray pulses to a scanning tunneling microscope to enable element-specific contrast with ultrafast time resolution and atomic-scale spatial resolution. This will enable studies of temporally and spatially resolved charge and spin dynamics of quantum point defects and surface chemical reactions.
- **Time-Resolved and Angle-Resolved Photoemission Spectroscopy (TR-ARPES) –** This end station enables time and angle resolved photoemission measurements to investigate dynamic processes in quantum materials including electron relaxation, exciton dynamics, evolution of spin-momentum locked states, and dynamics of correlated states.
- **Time-Resolved Laser-Induced Electron Diffraction and Attosecond Science (TR-LIED/ATTO) –** This end station is capable of time resolving the angular momentum distribution of gas-phase molecules probed by an intense mid-infrared pulse. The result will be the ability to create movies of molecular dynamics with sub-femtosecond time resolution and sub-angstrom spatial resolution.

Beamline	ARPES	STM	XAS/XRS	
Laser Mode(s)	>1 MHz, 800 W, 300 fs 100 kHz, 500 W, 40 fs	100 kHz: 550 W, 40 fs 230 W, 8 fs	100 kHz: 550 W, 40 fs 230 W, 8 fs	
XUV on Target	Range: 10-100 eV Bandwidth: 0.02 eV Photons: 10^9 s^{-1}	Range: 15-250 eV Bandwidth: 0.5 eV Photons: 10^{10} s^{-1}	Range: 10-300 eV Bandwidth: 50 eV Photons: 10^{13} s^{-1}	
Time Resolution	300 or 40 fs modes	40 or 8 fs modes	50 fs to sub-fs	
End Station(s)	TR-ARPES	TR-STM	TR-XAS	LIED / ATTO

Figure 2. Three beamlines deliver tailored light to four end stations. Photon flux, spectral range, bandwidth, and pulse durations available on target for each of the end stations are shown above.

1.3. A Research Ecosystem for Broadening Participation in Ultrafast Science

The NeXUS development project has resulted in the creation of a first-of-its-kind ultrafast facility designed to support researchers from a wide range of scientific disciplines. Transitioning from instrument implementation to facility O&M now requires bringing together an outstanding team of research scientists and technical and administrative staff to support a vibrant user program where members of a broad range of scientific communities can pursue their most ambitious goals in a highly collaborative, cutting-edge research environment. Thanks to its unique intersection of a high average power, ultrafast XUV light; suite of molecular and materials characterization end stations; highly trained research scientists, technical, and administrative support staff; and engaged participation by users, NeXUS will represent a complete scientific ecosystem (Figure 3). The goal of NeXUS O&M is to create both a facility and culture where scientific discoveries are accelerated because scientists of all career stages thrive. Successful NeXUS O&M will enable a diverse community of users to advance US competitiveness in fields ranging from energy conversion and catalysis to quantum material dynamics to ultrafast biology. During O&M NeXUS will become a focal point of interdisciplinary collaboration by enabling measurements that cannot be performed anywhere else in the US with potential to shape the future of ultrafast science.

Every aspect of this proposal for NeXUS O&M is guided by the goal to establish a scientific ecosystem around the NeXUS facility that will benefit the scientific community and reshape the future of the US research landscape. Figure 3 depicts the key elements required to create this ecosystem as well as the direct benefits that this organizational structure will provide to the broader scientific community. Shown in blue are the elements required to create and sustain this scientific ecosystem. In addition to the NeXUS facility, which has been constructed under the successful development project, successful O&M requires federal sponsorship to support a fully open access user program, a team of scientific and technical staff to enable user experiments, strong support from an existing Ohio State research infrastructure, and the engaged

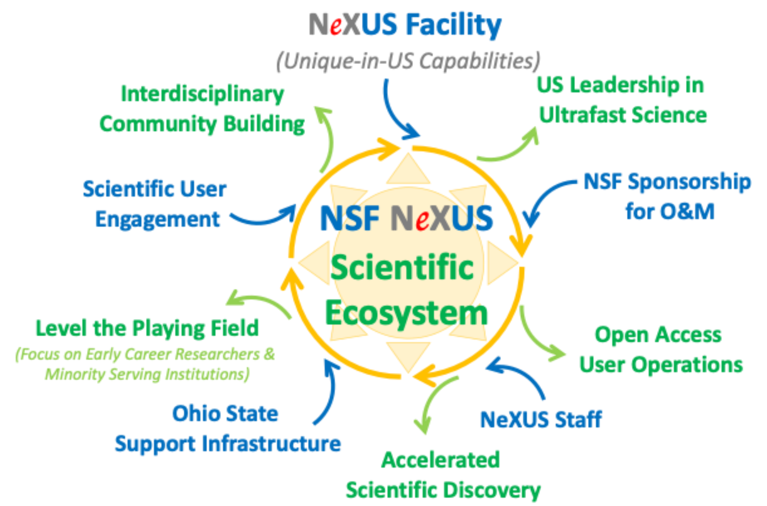

Figure 3. The goal of NeXUS O&M is to create a scientific ecosystem that will shape the future of ultrafast science. Blue arrows represent key elements required to create and sustain this ecosystem, and green arrows represent direct benefits of this ecosystem to the scientific community and society.

participation of a scientifically diverse community of researchers. Shown in green are the direct benefits that this ecosystem will provide to the research community. This includes open access to the NeXUS facility, supported by a highly skilled team needed to fully utilize these state-of-the-art capabilities. A strong focus on early career scientists as well as researchers from undergraduate and minority serving institutions will level the scientific playing field by providing researchers access to the most advanced tools currently available in ultrafast molecular and materials characterization. The net effect will be to accelerate scientific discovery by an interdisciplinary community of researchers and to establish US competitiveness in ultrafast science. Like a natural ecosystem, this organizational structure will create a positive feedback loop that will enable the impact of the NSF investment in NeXUS to grow exponentially with time.

To appreciate the benefits of successful NeXUS operation as a nimble, open-access user facility, one must first recognize the barriers researchers face that hinder them from pushing the scientific limits in their disciplines. This includes extremely limited access to the complex instrumentation necessary to probe molecular, material, and biological systems at the frontiers of time and space. Currently, ultrafast soft x-ray and XUV light sources exist in the laboratories of only a few groups across the US, primarily at large, well-funded R1 institutions. Even in cases where the needed instrumentation is accessible, taking full advantage of these resources requires a complex infrastructure to support successful experiments. This includes experimental planning; custom instrument modifications; data collection, processing, and analysis; and the many other collaborative interactions needed to take an experiment from conception to transformative scientific impact. Researchers operating outside of such a scientific ecosystem seldom succeed in realizing the impact of their best ideas, regardless of their individual level of creativity or innovation. This is particularly true for early career researchers and scientists working at primarily undergraduate and/or minority serving institutions. It is important to note that lack of accessibility to cutting-edge research infrastructure has not only limited the current state of science; lack of accessibility represents a major challenge to workforce training that is badly needed to broaden participation in the scientific enterprise and to maintain the competitiveness of US research and education moving into the next generation. The goal of this proposal is to define a technical and administrative structure where the NeXUS ecosystem will thrive. Consequently, NeXUS O&M represents the merger between technology experts who create instruments that push the limits of temporal, spatial, and state-resolved measurements and the community of researchers who can translate these measurements to answer the scientific questions of greatest impact.

1.4. Project Objectives

This proposal for NeXUS O&M focuses on five primary objectives:

1. Operate a thriving user program where the NeXUS system and staff support user experiments selected based on a competitive, open access peer-review process.
2. Create a culture and infrastructure where diverse researchers (scientific expertise, institution size, and career stage) thrive. Continuously expand the user base by effective outreach and engagement.
3. Expand facility capacity to support an increasing number of user experiments annually. This will be achieved by strategically expanding the staff and investing in process efficiency. The number of users which NeXUS can support annually will ultimately depend on the level of facility staffing.

4. Expand facility capabilities to keep NeXUS at the cutting edge of ultrafast science.
5. Utilize NeXUS to support workforce training and broaden participation in ultrafast science.

The full value of NeXUS will be realized through its users and their experiments, and this O&M proposal has been designed to maximize the impact of this significant NSF investment. The scientific impact of the facility and the number of experiments that can be supported annually depends primarily on the number and quality of the research scientists and staff available to support user experiments. Without sponsor support for O&M, NeXUS could not operate as an open access facility, and the impact of this investment on the future of ultrafast science would be largely unfulfilled. This proposal reflects our focus on investing in staff and describes how a ramp-up of staff support during the first three years of NeXUS O&M will lead to a substantial increase in user access, eventually reaching a steady capacity. Based on an enthusiastic response from the community, we anticipate that the facility will rapidly become oversubscribed, and that the NeXUS team will need to identify ways to expand as it seeks to meet an increasing user demand.

1.5. Team Qualifications

O&M of the NeXUS facility will be led by scientists committed to the vision of NeXUS, carried out by a professional staff directly supporting users, and supported by a talented group of co-principal investigators (PIs) with complimentary expertise in the variety of experimental capabilities at NeXUS. **Robert Baker**, Professor of Chemistry & Biochemistry with expertise in ultrafast XUV experiments, will be the Facility Director. **Louis DiMauro**, Professor of Physics with expertise in attosecond electron dynamics and high harmonic generation, will be the Deputy Director. Both researchers have strong ties to the community of researchers who will use NeXUS and the community of scientists and engineers who are operating user facilities around the world. They have designed an Organizational Structure (Section 5.2) and Governance Structure (Section 5.6) based on the successful examples of other scientific facilities and considering the unique scope and objectives of NeXUS.

The heart of the NeXUS facility will be a team of highly qualified scientists, technicians, and administrators who support user experiments (at all stages), maintain the facility to ensure it meets user needs, and continuously improve the facility to grow its capacity and capabilities. **TJ Ronningen**, a Research Scientist who brings more than 10 years of industry experience in project management and process efficiency, will serve as Facility Manager. Four **System Scientists** will provide technical expertise needed to support and maintain the complex laser system and end stations and will work directly with users to plan and execute experiments. Four **Technicians** will have established expertise in system components and engineering principals necessary to support facility maintenance. These Technicians will also develop skills to operate the NeXUS systems and Facility, and under guidance of System Scientists will work directly with users to support their experiments. Two **Coordinators** will support the staff and users to enable efficient execution of all facility goals and functions. NeXUS has analyzed the tradeoffs necessary, at this early stage, and selected a scenario that balances near term success—bringing in users and supporting impactful experiments—with long term success—establishing effective procedures, effective cross-training, and ongoing development. The staffing level and roles are described in Section 5.5.

Three co-PIs will provide support to the NeXUS leadership, staff, and users to ensure the facility has the breadth and depth of expertise for a successful launch. **Jay Gupta** (Professor of Physics), **Roland Kawakami** (Professor of Physics), and **Claudia Turro** (Professor of Chemistry) will each take on three roles within their domain of expertise. First, they will provide scientific and professional mentorship to NeXUS research scientists within their respective fields. Mentorship will include technical guidance on the implementation of experimental techniques and critical review of the details of planned experiments. Second, they will lead the development of next-generation scientific capabilities with the goal to keep NeXUS at the cutting edge of this rapidly evolving field throughout the duration of this 5-year project and beyond. Third, they will serve as ambassadors to the wide-ranging research communities across chemistry, physics, biology, and materials science who can take advantage of NeXUS. The co-PIs will present talks and workshops that share about NeXUS capabilities, support the community of users within their research fields, and encourage and enable researchers to make use of NeXUS to advance their research objectives.

1.6. Building an Engaged User Community

The engaged participation of the broader user community is critical to the success of the NeXUS project. To fulfill its mission, NeXUS must become a highly subscribed facility serving a diverse cross-section of researchers. From the inception of the development project, the NeXUS team has been engaged in building an active user community. For example, NeXUS has hosted two user workshops aimed at educating future users about NeXUS capabilities and soliciting feedback from the community regarding infrastructure priorities and first science to be pursued as the NeXUS facility comes online beginning this year. The 2020 workshop attracted the participation of >200 individuals from 75 institutions and 13 countries, documenting the tremendous interest in this facility by the national and international community. On the second day of the workshop, topical breakout sessions featured 27 short proposal talks by external participants on "Killer Applications" of the NeXUS Facility. To demonstrate the impact of NeXUS across scientific disciplines sponsored by various NSF divisions, Table 1 shows the number of NSF grants awarded per division to the 27 Killer Application presenters (all from outside Ohio State). The only guidance given to presenters was to propose a potential transformative first experiment that could only be performed utilizing the unique capabilities of the NeXUS facility. As these numbers show, NeXUS capabilities are attracting users from a wide range of disciplines.

*Table **1**. NSF grants awarded per division to the presenters and contributors at the two NeXUS user workshops.*

NSF Divisions	2020 Speakers	2022 Authors
CHE	56	15
DMR	21	3
PHY	15	32
ENG (ECCS, CMMI, CBET)	15	0
MCB	0	5

In 2022 NeXUS hosted a second user workshop aimed at soliciting feedback from the user community on defining the first science–the highest scientific priorities–towards which NeXUS capabilities should be utilized. This event likewise benefited from enthusiastic user engagement with representation from 120 individuals from 59 institutions and 12 countries in the virtual plenary session. Following the plenary session, 4 in-person working groups convened for 2 days to evaluate scientific priorities for NeXUS in the following topical areas:

1. Attosecond Electronic and Molecular Dynamics
2. Liquid Phase and Interfacial Chemical Dynamics
3. Quantum Materials and Condensed Matter Physics
4. Dynamics in Biological Systems

These working groups consisted of 20 experts from these respective fields (Table 3). Following their 2-day evaluation and subsequent writing, the panelists produced the NeXUS First Experiments Document (attached) that describes high impact scientific priorities from each of these disciplines where the unique capabilities provided at NeXUS are poised to have a transformative impact. This document is a statement provided directly from the future user community on the compelling need for open-access operations of the NeXUS facility. Based on this high level of participation by the broader community, even from the earliest days of the NeXUS development project, we expect that this facility will become rapidly over-subscribed and that creative solutions by the staff will be needed to maximize user engagement and scientific throughput at NeXUS. The next NeXUS user workshop is scheduled for summer 2024, where the NeXUS team will announce experimental capabilities and solicit proposals for the first round of user experiments.

2. Intellectual Merit

The potential of attosecond light pulses to impact a wide range of scientific disciplines was recognized by the 2023 Nobel Prize in Physics to Pierre Agostini (Ohio State, US), Ferenc Krausz (MPQ, Germany) and Anne L'Huillier (Lund, Sweden)[1]. Despite this potential for impact, the technical complexity of attosecond and femtosecond XUV light sources has inhibited their application by a broad community of scientists and engineers. The need to make these tools widely accessible has been recognized by multiple recent reports from federal agencies[2], including the National Academy of Science[3, 4], which endorsed the development of national user facilities based on these technologies to create a quantum leap in US ultrafast science. It is worth noting that the US has recently lagged Europe in providing community access to these advanced tools, which have been supported in Europe through the Extreme Light Infrastructure and Laserlab-Europe. The NeXUS development project has delivered on its promise to create a user facility capable of putting these tools into the hands of a broad community of scientific users. The aim of NeXUS O&M is to create a scientific ecosystem around this facility that will propel US researchers to the forefront of ultrafast science and enable new discoveries based on access to these cutting-edge tools. To accomplish this, the NeXUS facility will operate as an open-access user program to advance **the frontier** by providing direct visualization of electron interactions and associated chemical, material, and biological dynamics at the ultrafast timescale. Because intellectual merit of NeXUS touches upon many facets of science, technology, and engineering, the following sections are organized based on community-identified research priorities as outlined in the 2022 NeXUS workshop report entitled "NeXUS 2022 – First Experiments Document" (attached). Scientific challenges to be addressed by NeXUS include the ability to produce the complete molecular movie including all constituents, *i.e.*, electron and nuclei, during a chemical reaction, the efficient capture and storage of sunlight using artificial systems mimicking the precision of natural photosynthesis, and the ability to master information transport on the atomic scale to create new quantum information technologies. Currently limiting these advances is the inability to observe and control energy and information transport on the scale of individual electrons and atoms. These community-identified grand challenges call for the creation of a national user facility capable of observing dynamics on the electron's fundamental scales of time and space, *i.e.*, attosecond and angstrom. NeXUS's research capabilities are designed to enable transformative rather than incremental advances in the areas of molecular design, quantum materials and energy science. Accordingly, NeXUS fills a key strategic gap in the US research infrastructure.

2.1. Attosecond Electronic and Molecular Dynamics.

What scientific questions motivate the study of electron dynamics with attosecond resolution? Among many examples of dynamic processes driven by electron motion are those that lead to the formation and dissolution of molecular bonds, correlated dynamics in the condensed phase, and collective electron motions in nanoparticles and at surfaces. The emerging field of attochemistry examines how electron dynamics influence photochemical processes[5, 6]. For example, although we have a very accurate description of many molecular processes using the Born-Oppenheimer (B-O) approximation, which assumes that electrons adiabatically adjust to nuclear motion, it is well understood that the B-O approximation often fails, especially when there are degenerate or nearly degenerate electronic states involved in the dynamics. Understanding the breakdown of the B-O approximation and how electronic and nuclear degrees of freedom are dynamically mixed is fundamental for understanding many chemical reactions involving light nuclei or very repulsive molecular potentials.

The study of correlated interactions between electrons is similarly of fundamental interest. The formation of chemical bonds, the correlated behavior of electrons in solids, and the response of extended systems to the sudden removal of an electron by photoionization (radiation damage) are all dominated by correlation at short times. Although much information is available in the spectral domain, processes that involve interfering pathways cannot be characterized by steady-state absorption lines and require time-resolved spectroscopy. Coherent attosecond pulses offer the most direct route to understanding multi-electron correlations and coherences on the natural timescale of the electron, a key requirement in implementing control of matter at the level of the electron.

In ultrafast chemistry, charge migration (CM) stands out as an important milestone[8-10]. This correlation-driven, multi-electron response is typically initiated when a molecule is forced out of equilibrium by rapid ionization or excitation. The electrons react first, over timescales approaching the attosecond[11, 12], with the nuclei following on the femtosecond scale, and potentially leading to a host of downstream physical or chemical processes such as dissociation, charge transfer and photoelectric energy conversion[8, 13]. Figure 4 illustrates how brominated alkane, alkene and alkyne molecules differ in the degree of coherent charge migration. Outstanding questions include: Which molecules are expected to support CM? Does CM manifest in generic ways so that its periodicity and visibility can be predicted to follow simple rules? Does the way in which CM is initiated influence how it proceeds? Are there generic mechanisms that enable sustained CM motions in molecules?

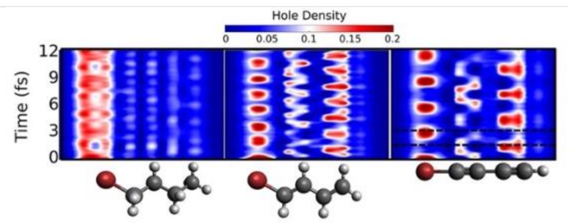

Figure 4. The role of chemical bonding in CM in the bromine-functionalized four-carbon chains visualized by TD-DFT. Time-dependent hole densities along the chain show that the alkane does not support CM. In both the alkene and alkyne cases, CM occurs via hopping, with the C≡C case being slower than the C=C case. From [7].

The rescattering mechanism[14, 15] at play during the interaction of intense, femtosecond laser pulses with gas phase matter, is a fundamental process in ultrafast science. This mechanism is responsible for the generation of XUV attosecond pulses used at the NeXUS facility and also has the demonstrated capability to image atoms in molecules with few picometer and femtosecond spatio-temporal resolutions via LIED[16]. Previously, using LIED with a 1 kHz repetition rate laser, it was found that the cage of C_{60} molecules exposed to intense mid-infrared pulses undergoes deformations without breakup via an energy deposition mechanism driven by stimulated impulsive Raman scattering[17]. The 2022 NeXUS working groups recognized that the superior data collection rates enabled by NeXUS is a game changer for LIED. For example, this could enable studies of the deformation process for endo-fullerenes, *e.g.* Lu_3NC_{80} doping. In addition, it is known that LIED is successful in retrieving the structure of small molecules (N_2, O_2, C_2H_2, OCS), but as the molecular complexity is increased, structural retrieval becomes more difficult, since more and more bond lengths need to be identified unambiguously from the radial distribution function requiring much higher sampling rates, which will be uniquely enabled at NeXUS. Ideal targets for this study are various saturated and unsaturated hydrocarbons. Coupling the LIED and attosecond capabilities of the NeXUS facility will provide users the ability to film the complete molecular movie.

2.2. Liquid Phase and Interfacial Chemical Dynamics.

The ability to view the flow of charge and energy in photoexcited molecules and at interfaces is a grand challenge spanning multiple disciplines. Within the chemical sciences, these include efficient solar energy conversion processes such as photochemical and photocatalytic chemical reactions and ultrafast biological processes such as molecular-level protection against radiation damage. To understand these processes, ultrafast spectroscopy in the IR, visible, and UV spectral regions has been widely applied. Recently, the potential of ultrafast pulses in the XUV and soft x-ray spectral range has become highly attractive[18-23]. The large cross section of core-to-valence transitions in this energy region, which in the case of 3d transition metal M-edges is comparable to that of visible-light excitation, make it a powerful probe of element-specific dynamics that is extremely sensitive to oxidation state, spin state, and coordination environment[24-28]. This will enable NeXUS users to directly observe photochemical reactions in molecules and at interfaces with unprecedented time resolution and exquisite chemical state sensitivity. In these measurements, observing element-specific evolution of oxidation state and spin configurations will provide real-time mapping of charge and spin transport in systems ranging from small molecules to biological systems to complex material interfaces.

The vision driving these experiments is the desire to not only understand the outcome of chemical reactions, but also to understand and control the pathways and mechanisms that ultimately guide chemical reactivity. On attosecond to femtosecond timescales, this involves wave packet transitions through conical intersections, where pathway splitting determines the outcome of the reaction[29-31]. To date, most work in this field has focused on isolated molecules in the gas phase due to the low photon flux of most lab-based XUV light sources and the high XUV absorption of liquid samples. In the past, these two factors have combine to make ultrafast XUV studies in solution phase impossible for most systems of interest[20]. The NeXUS facility offers a three order of magnitude increase in XUV photon flux compared to traditional HHG light sources (Figure 1). This increased flux provides the unique opportunity to study dynamics of photochemical and biological systems in their native solvation environment. This ability will allow NeXUS users to address a host of important scientific questions: For example, how does the chemical environment influence the early dynamics of a photochemical reaction? Given that vibrational motion is sensitive to solvation, what is the influence of solvation environment on the very fast early dynamics through a conical intersection or across a transition state? Questions such as these will be addressed for the first time at NeXUS by users with interests ranging from molecular photochemistry to chemical reactions on surfaces to ultrafast biological processes.

During the 2022 NeXUS user workshop, specific areas of community interest that would lead to high-impact discoveries were identified as initial targets for the NeXUS facility. These include understanding intersystem crossing and energy relaxation processes in Earth-abundant 3d transition metal photocatalysts, studying interfacial charge transfer in dye sensitized solar cells, and observing charge and energy transfer from plasmonic nanoparticle systems. Considering ultrafast processes in biological systems, the 3d-metal M-edge transitions give access to a wide range of metal sites in biology, such as the role of hemes in long-distance electron transfer. Sulfur and phosphorus atoms are also ubiquitous in biological molecules, and specific molecular targets that use them as reporters for ultrafast proton dynamics should be investigated.

One of these areas is to probe proton-coupled electron transfer (PCET), a process that is critical for biological energy conversion as well as energy transformations in artificial systems[32-37]. Additionally, the use the broadband probe with access to multiple element edges will provide a powerful measurement tool for understanding the ultrafast processes involved in medically relevant photodynamic therapies. This will include measuring charge and spin-resolved dynamics in molecular systems designed to activate or deactivate biological systems and/or deliver drugs upon photoexcitation.[38]

2.3. Quantum Materials and Condensed Matter Physics.

The coupling and energy transfer between extended and localized states in solids is becoming increasingly important for a wide variety of applications spanning heterogeneous catalysis to next-generation information technologies. For example, photocatalysis in copper oxides involves transferring band edge photoexcited carriers to adsorbed molecules localized to catalytically active sites on the surface such as step edges and defects[39-42]. Atomic-scale characterization of catalyst surface structure and molecular orbital states can be compared to first-principles theoretical calculations to better understand rate- and selectivity-limiting reaction steps. These comparisons, however, are often limited to highly simplified model systems, motivating the development of new tools for characterizing the structure and dynamics of more complex materials with high spatial and energy resolution.

In information technologies, the miniaturization of electronic components such as transistors to nanoscale dimensions is nearing fundamental limits imposed by the discrete atomic nature of the impurities in semiconductor materials. Quantum device simulations of nanowire FinFET transistors for example, indicate significant variations in the threshold voltage, ON and OFF currents depending on the random placement of dopants in the channel[43, 44]. Beyond scaling of conventional technologies, characterization and control over single atoms are a basis for approaches to quantum information processing in the solid state[45, 46]. These next-generation technologies require not only atomic-scale characterization of defect structures in solids, but also control over their dynamics down to ultrafast time scales.

As noted in the First Experiments Document, the NeXUS facility has a unique suite of capabilities to address the critical gap in correlating atomic scale structure in complex materials with relevant charge, spin, and photo dynamics. The STM end station and beamline extend the capabilities of STM for atomic-resolution imaging, tunneling spectroscopy and atomic-manipulation, through the power of femtosecond- and element-resolved x-ray photoexcitation. The TR-XAS/XRS end station and beamline provides sensitivity for probing chemical-states of the atoms in complex materials with high temporal resolution. The TR-ARPES end station and beamline has the capability to probe time-dependent band structure and carrier energy relaxation in 2D and quantum materials. In totality, NeXUS provides the user cross-cutting tools for performing multi-dimensional ultrafast studies.

TR-ARPES provides access to dynamics of many-body interactions including electron-electron, electron-phonon, and quasi-particles as well as excited state scattering and relaxation processes. This is of critical importance for fundamental understanding and technological applications of quantum materials. As highlighted in the First Experiments Document, two-dimensional (2D) semiconductors and semimetals provide a versatile materials platform spanning both fundamental science (e.g. topological and many-body states) and technological applications (e.g. optoelectronic and quantum devices and ultrasmall transistors). Specifically, monolayer and bilayer transition metal dichalcogenides (TMDC) are ideal systems because they (1) possess fascinating *electrically-tunable* excitonic, ferroelectric, topological, superconducting, and spin and valley phenomena, and (2) enable full access to its energy- and momentum-resolved quantum states due to its ultrathin structure that lies within the penetration depth of ARPES.

The participants at the 2022 NeXUS workshop highlighted several investigations that require the unique capabilities offered at the NeXUS facility. First, researchers are interested in exploring optoelectronic properties in direct-gap monolayer TMDCs (e.g. MoS_2, WS_2, $MoSe_2$, WSe_2) and their stacked heterostructures by investigating dynamics of bright and dark excitons, moiré excitons, and valley relaxation. The first results on excitons from momentum microscope-based TR-ARPES appeared in 2020[47-52]. Figure 5 shows recent work on the valley dynamics of excitons in monolayer TMDCs[52]. Second, bilayer $MoTe_2$ and heterostacked/twisted $MoTe_2$ are interesting systems because quantum anomalous Hall effect (QAHE), superconductivity, and ferroelectricity have been predicted or observed[53-57]. Third, spin-related properties can be studied including proximity effects in monolayer and bilayer TMDCs when placed adjacent to magnetic films or chiral molecular films. For these studies, the spin-valley coupling in monolayer TMDCs allows the valley polarization to be a proxy for spin polarization for cases when the spin-valley coupling is very strong[58]. Thus, valley-dependent charge transfer to adjacent magnetic or chiral layers will occur due to their spin-sensitivity[59, 60].

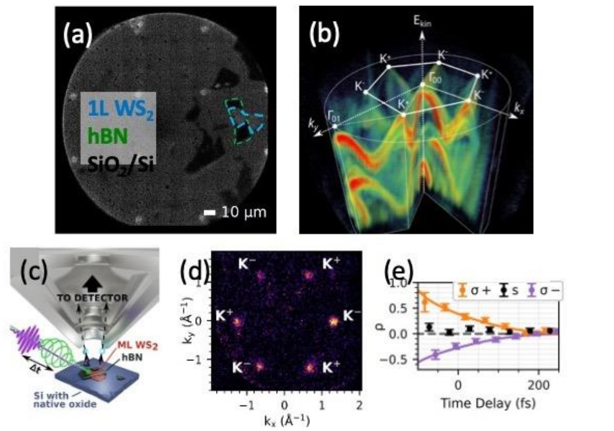

Figure 5. (a) Real space image of monolayer WS2 on hBN. (b) Ground state band structure measured by ARPES. (c) Schematic of optical pump, XUV probe for TR-ARPES. (d) An energy slice showing non-equilibrium electrons at the K+ and K- valleys of the conduction band. (e) Valley polarization vs. time delay for circular polarizations (s+ and s-) and linear polarization (s) of the optical pump pulse. From [52].

Another unique capability of the NeXUS builds on the recent demonstration of element-resolved STM with single atom sensitivity, Figure 6 shows a single Fe atom image in an organometallic molecule[61]. To uniquely identify the atom, the x-ray photocurrent was collected by the STM tip as the x-ray energy was scanned over the element-specific core-hole transition. Though the synchrotron source used in this study provides access to these element-specific absorption edges, the ability to combine these measurements with dynamic information is limited. This is because in contrast to x-ray pulse durations at synchrotrons, which are hundreds of picoseconds, the NeXUS STM beamline will provide access to XUV and soft x-ray light with femtosecond pulse durations. This will enable a unique combination of femtosecond-resolved x-ray and surface photovoltage spectroscopy that will be used to directly characterize carrier dynamics in quantum materials in the vicinity of atomic defects that can be uniquely identified. Such experiments can establish for the first time how quantum coherence properties of solid-state qubits depend on aspects of the local environment, such as proximity to interfaces and other defects.

3. Broader Impacts

3.1. Community Engagement and Public Education

As a unique-in-the-nation laser facility, NeXUS provides the opportunity to engage and educate the broader public around science and technology enabled by lasers. This includes the important role of understanding and controlling electron motion to enable new technologies for solar energy conversion, energy storage, and information storage and processing. These fields represent areas of significant research overlap with NeXUS that will resonate with the broader public. Our engagement efforts will build on the significant enthusiasm following the 2023 Nobel Prize in Physics related to attosecond electron dynamics. Building on these unique opportunities and recent momentum, the NeXUS team is committed to finding innovative and impactful ways to utilize the NeXUS facility and its staff for public outreach and engagement. Two specific opportunities for public outreach are described below.

First, Ohio State hosts an annual event called the Breakfast of Science Champions. This activity provides opportunities to Columbus City middle school students, invited from districts with a high percentage of potential first-generation college students, to experience the excitement of STEM research. At this event middle school students and their teachers spend a morning on Ohio State campus, where they learn about career opportunities in science and how to prepare for college. Then they participate in a series of hands-on experiments hosted by faculty, students, and staff. The goal of this program is to break down stereotypes about

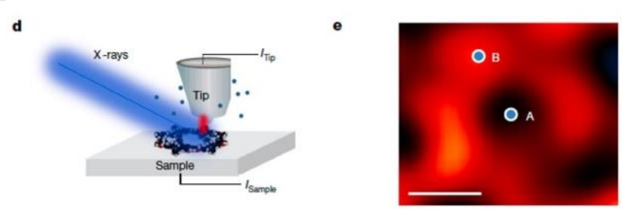

Figure 6. (d) Schematic of SX-STM in the tunnelling regime. (e) STM image of a single supramolecular ring measured with the SX-STM setup. Position A and B correspond to the tip position away and over the Fe atom. From [61].

science and inspire the students to pursue STEM education in high school and beyond. The NeXUS director (Baker) has participated in this event every year since its inception in 2016 (apart from COVID years). This activity has a broad reach with 150 middle school students participating in 2023. We propose for NeXUS staff to participate in this event by forming a station designed to teach young students about applications of lasers in everyday life and their role in advancing new technologies for energy conversion and information processing.

Second, NeXUS plans to partner with the Ohio State STEAM Factory to create an annual public outreach event around the celebration of the International Day of Light. The mission of the Ohio State STEAM Factory is to bridge the gap between campus researchers and the Columbus community by disseminating research and knowledge from the university to the local public in a way that is accessible, approachable, and fun. The International Day of Light is designated as May 26 and celebrates the first successful operation of the laser in 1960; this day is now dedicated to strengthening scientific cooperation and harnessing its potential to foster peace and sustainable development. The planned public outreach event, jointly hosted by NeXUS and the Ohio State STEAM Factory, is inspired by a similar, highly successful event held annually at ELI-ALPS with hundreds of participants. The goal is to bring as many individuals as possible from the local community to Ohio State campus to learn about light, NeXUS, and the many societal benefits of lasers and optics in a format that is engaging and accessible. We envision that the event will include a keynote talk by an Ohio State scientist geared to a public audience, as well as related talk by a member of the STEAM Factory with a background in public communication and/or education. It is foreseeable that the recent Nobel laureate from Ohio State, Prof. Pierre Agostini, will present a talk on applications of attosecond science. The event will also include booths for children and teens where they will learn about laser safety, participate in optics-based demonstrations, and learn about applications of lasers and optics with potential for major societal impact.

3.2. Impact of NeXUS on Students and Early Career Researchers

Partnership for Research and Education in Chemistry (PREC) is an NSF program designed to establish collaborations between minority serving institutions (MSIs) and NSF-supported centers with the goal to increase recruitment and retention of underrepresented students while also promoting accessibility to state-of-the-art NSF-sponsored facilities. NeXUS enthusiastically shares these goals, and the NeXUS team has initiated discussions with faculty from two MSIs with the goal to establish meaningful interactions in preparation for submitting a PREC proposal at the next call. As described below, these partner institutions will also provide strong applicants for a newly proposed Research Experience for Undergraduates (REU) that NeXUS will establish during the second year of O&M. Through this REU program and future PREC collaborations, students and faculty from minority-serving partner institutions will have the opportunity to learn about the NeXUS facility, establish collaborations with NeXUS staff, and gain hands-on experience using the NeXUS system. These activities enable meaningful research collaborations, effective training of early career researchers, and access to state-of-the-art instrumentation in ultrafast x-ray science. In addition, PREC activities will significantly benefit the NeXUS facility by forming long-term relationships with partner institutions that will serve as an active and engaged user base for the facility. During the development project, the NeXUS team has already established close interactions with faculty from Florida International University (Miami, FL) and Central State University (Wilberforce, OH). NeXUS will continue working with both universities to prepare for a PREC and support the REU program. A PI from NeXUS will travel annually to one of these partner institutions and present a seminar focused on research opportunities at NeXUS followed by an informal lunch discussion with students. Interested students, postdocs, and faculty will be invited to participate in a special session at the annual NeXUS Users Meeting where NeXUS staff will review facility capabilities and provide guidance on submitting a strong user proposal. Travel funds to support these activities have been requested in the attached budget.

NeXUS can provide unique training opportunities for undergraduate students in chemistry, physics, materials science, and biology. To facilitate these training opportunities, we will establish an REU program that is targeted for MSIs with an established research focus that can benefit from the NeXUS capabilities. Both partner institutes listed in Table 2 will provide a pool of qualified and engaged applicants to this REU program, and we expect the number of partnerships to expand with time. Selected REU students will have the opportunity to conduct research at Ohio State, including learning about and utilizing the unique techniques and equipment available at NeXUS. NeXUS PIs will serve as faculty advisors to the REU students. NeXUS staff will mentor REU students on their individual projects and support experiments at NeXUS. This REU program will be integrated into an existing, highly successful REU program administered through the Center for Emergent Materials, an NSF MRSEC at Ohio State. This collaboration will support professional development for the students, including a graduate school application panel, NSF Graduate Research Fellowship panel, workshops on preparing scientific posters, networking lunches with faculty and graduate students, and several social activities. In this project, funds are requested for four REU students per year.

Table 2. MSIs with research focuses closely linked to NeXUS capabilities who have agreed to support a collaborative REU program.

Institution	Linked Research Focus	Faculty Lead(s)
Florida International University	Dynamics in solids, at atomic scale	Daniela Radu Cheng-Yu Lai
Central State University	Surface science	Suzanne Seleem Leanne Petry

Because NeXUS will seek to engage early career researchers who may not have sufficient funding to support travel to facilities, we will establish an Early Career Travel fellowship. In each proposal review cycle the Proposal Review Panel (PRP) will identify the strongest proposal from an early career researcher to receive this fellowship. These funds will be used to support travel for the PI and one student to travel to NeXUS for two weeks to perform the proposed experiments. We believe this program will help level the playing field for early career researchers and encourage NeXUS proposals from talented faculty who may not otherwise be able to utilize the facility due to the cost of travel. To further mitigate the travel/access barrier, we will also implement remote user access at NeXUS. Remote use is particularly well suited for the end stations with sample microscopy. For example, after loading a sample STM experiments can be operated almost entirely remotely. These experiments are also particularly visual as they provide direct imaging of materials with atomic scale spatial resolution. The development of remote access technologies will also support engagement of undergraduates, and even secondary schools, across the nation.

4. Results from Prior NSF Support

NeXUS O&M will build on the results of the successful development project as described here. We also describe two closely related NSF projects, an AccelNet Design project in which NeXUS is one of the US partner institutions developing an international network of networks, and an NSF MRI award to incorporate a closed-cycle cryo cooler to the TR-ARPES end station at NeXUS.

4.1. Principal Investigator Baker, Mid-scale RI-1 Award

"Mid-scale RI-1 (M1:IP): NSF National eXtreme Ultrafast Science (NeXUS) Facility" (Award 1935885) provided $10,484,658 to **L. Robert Baker** (Principal Investigator), **Claudia Turro**, **Roland Kawakami**, **Louis DiMauro**, and **Jay Gupta** from September 16, 2019 to July 11, 2023. Published journal articles: [18, 52, 62].

4.1.1. Intellectual Merit

The NeXUS Development project was awarded in 2019. It was one of the inaugural awards made by NSF within the newly implemented Mid-Scale Research Infrastructure program, and it is the first and only mid-scale award administered by the Division of Chemistry. The major goal of this project is to build a first-of-its-kind light source in the US, couple that light to a suite of molecular and material characterization end stations, and serve as an open-access user facility serving the entire ultrafast community. When the development project is completed, NeXUS will be the first user-accessible attosecond light source in the US. Figure 7 shows an overview of the NeXUS system. A detailed description is provided in the attached Facilities, Equipment, & Resources description.

The NeXUS system consists of a kW-class ultrafast laser with nonlinear pulse compression and a high-power optical parametric amplifier (OPA) for wavelength conversion, three custom x-ray beamlines designed to deliver tailored femtosecond and attosecond light, and four scientific end stations. Of these four end stations, two were obtained commercially (ARPES and STM) and two were designed and constructed in-house by Ohio State graduate students and postdocs with the help of external collaborators (XAS/XRS and LIED/ATTO). At the time of writing this proposal, all beamlines and end stations have been assembled and the kW-class ultrafast laser has been delivered and is being installed in the NeXUS lab.

Both custom end stations were designed to optimize data collection while maximizing flexibility for future user experiments. For example, the design team on the XAS/XRS sub-system has implemented a sample chamber that is compatible with both transmission and reflection geometries depending on user

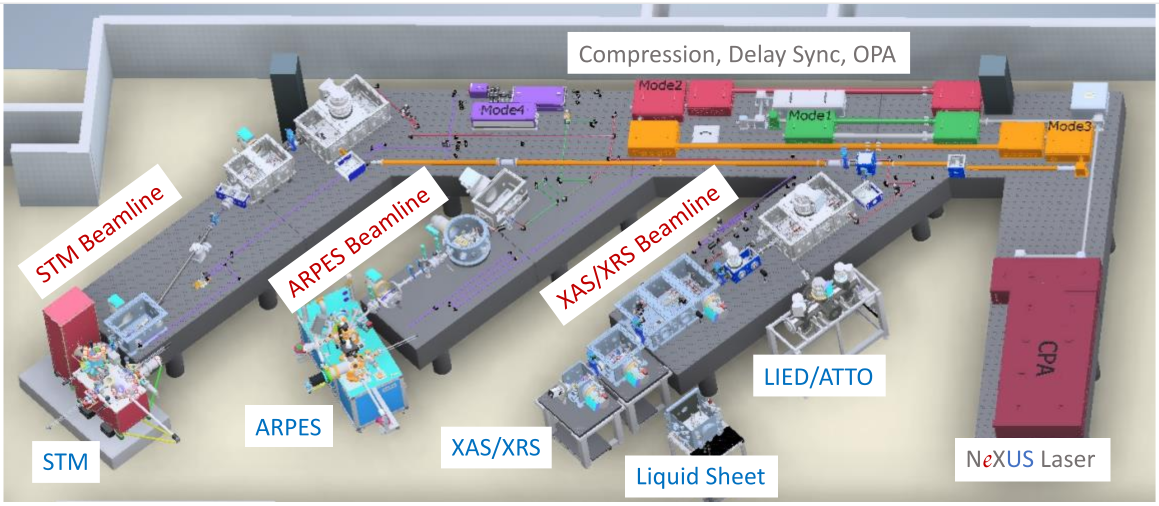

Figure 7. Overview of the NeXUS system consisting of a kW-class ultrafast laser with nonlinear pulse compression and a high-power OPA for wavelength conversion, three custom x-ray beamlines designed to deliver tailored femtosecond and attosecond light to four separate scientific end stations. Components obtained commercially are labeled in blue and custom components designed and fabricated in-house are labeled in red.

sample requirements. This sample station also supports variable-angle reflection measurements from which users can obtain the complete time-dependent complex refractive index of a material across core-hole resonances. Additionally, a separate liquid sheet chamber will create flat liquid jets of sub-µm thicknesses for the study of attosecond and femtosecond dynamics of photochemical complexes in solvated environments. The LIED/ATTO end station was also designed and built in-house. In this end station, attosecond electron dynamics are probed by dual TOF spectroscopy at 200 kHz sampling rate. This end station also supports user experiments in LIED, wherein molecular dynamics are probed on the femtosecond time-scale with sub-angstrom spatial resolution. All beamlines and end stations in the NeXUS facility have been built with the goal to maximize performance and flexibility to support a wide range of possible future experiments based on user-defined interests and priorities.

In addition to these two end stations designed and constructed in-house, two commercially procured end stations are fully functional. Figure 8 shows results from the ARPES and STM end stations. Panel A shows the measured band structure of epitaxial graphene grown on silicon carbide measured in k_x and k_y momentum space using the ARPES end station with its equipped helium lamp. Panel B shows the herringbone reconstruction of a Au(111) surface measured with atomic resolution on the STM end station.

Beyond the actual NeXUS laboratory, several ancillary support spaces have been developed to ensure optimum conditions for facility operations and to support a wide array of potential user experiments. This includes separate rooms for experiment control, safe lab entry, vacuum pumping, component chillers, and standard and custom gas delivery systems to the various beamlines and end stations. A custom HVAC system provides control of lab climate to within ±1 °F and ±5% relative humidity. A careful HEPA filtration system and cleanroom protocols ensures that the lab functions as an ISO6 (Class 1000) cleanroom[63], which is confirmed by particle count measurements. Push buttons for laser shutdown are distributed at entry/exit points and near each of the experimental end stations to support safe operation of the laser. A laser interlock system automatically updates lab access protocols depending on the state of the laser to prevent any unauthorized lab access during laser operation. CCTV cameras provide a complete view of the lab that can be seen from the lab entry chamber as well as the user control room for live safety monitoring. A hard wire ethernet data server connects the NeXUS lab to the user control room for real-time instrument control and data acquisition and processing at GB/s transfer speeds. The NeXUS system is operational pending completion of the laser installation and verification (expected in December 2023).

To ensure that the NeXUS Development project delivers the entire proposed capabilities, progress is tracked against a “project execution plan” that defines its scope, budget, and timeline. The plan enables the tracking of progress using an Earned Value Management approach. In Earned Value Management, the Schedule Performance Index (SPI) tracks progress against planned schedule, and the Cost Performance

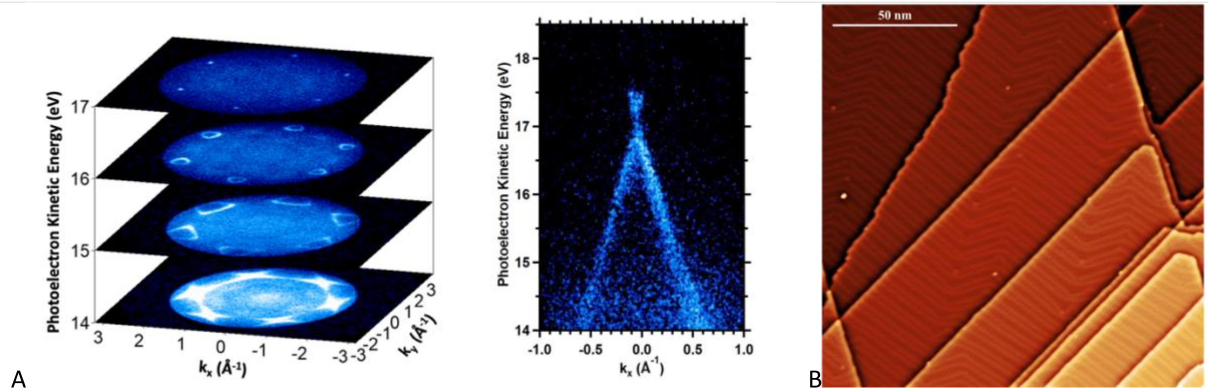

Figure 8. ARPES spectrum of epitaxial graphene on SiC(0001) substrate taken with momentum microscopy (k-space) mode (A). Left: several representative k_x vs k_y contours at different energies, featuring six Dirac cones. Right: E vs. k_y cut across one of the Dirac cones. Energy resolution of 25 meV and momentum resolution of 0.01 Å^{-1} have been demonstrated. A topographic STM image of the Au(111) surface. There are multiple flat terraces visible, which are separated by single Au(111) steps. The characteristic (22×√3) "herringbone" reconstruction is visible on the terraces. (B). Both ARPES spectra and the STM image were taken at NeXUS.

Index (CPI) tracks performance against planned budget. Currently, both indices are in the expected range, and their trends are to stay within range through project completion in December 2024.

To disseminate the results of these development efforts, NeXUS investigators have presented information about NeXUS at numerous scientific conferences[64-69], published journal articles that have included developments and contributions from NeXUS researchers[18, 52, 62], maintained a facility website, and published a quarterly newsletter. Other key highlights of the NeXUS development project include establishing memoranda of understanding (MOUs) and strong working relationships with the University of Michigan ZEUS project and Arizona State University CXFEL project, which represent two additional NSF-sponsored mid-scale facilities dedicated to creation of ultrafast, high intensity light. We have also established an MOU and enjoy a close working relationship with the European Union ELI Attosecond Light Pulse Source (ELI-ALPS). Importantly, PI Baker spent 4 months at ELI-ALPS as a Distinguished Fulbright Scholar interacting closely with its Science Director (Dr. Katalin Varjú) and Managing Director (Dr. Gábor Szabó) as well as numerous beamline scientists and staff. During this experience, Baker learned about ELI-ALPS user operations and performed experiments on their beamlines most closely related to NeXUS. Accordingly, the NeXUS team is well-poised to work productively with these closely related light source facilities in the US and Europe and to implement best practices and lessons learned in operations of a state-of-the-art, open access laser facility. These interactions also attest to the ongoing success of the NSF Mid-Scale Research Infrastructure program to coalesce an international community of scientists with shared interest in ultrafast, high intensity laser science.

4.1.2. Broader Impacts

The major broader impact of this project is the development of an open-access user facility serving the entire ultrafast community. Accordingly, this facility will fill a strategic gap in the US scientific capabilities identified by the National Academies[3]. This will level the playing field by providing a broad community of scientists, including early career and researchers from minority serving and undergraduate institutions access to the most advanced tools currently available in ultrafast molecular and materials characterization. To ensure broad participation, the NeXUS team has hosted two successful user workshops with >200 individuals from 75 institutions and 13 countries with another workshop planned for 2024. NeXUS has also organized meetings with potential users outside of academia, including Intel Research & Development and the Air Force Research Lab.

4.1.3. Potential Overlap

The NeXUS Development project will overlap in time with the proposed O&M project for about six months. Because the transition from NeXUS development to facility operations will require an enormous transfer of working knowledge from graduate students and postdocs (NeXUS design and assembly teams) to professional staff, this overlap is essential for an effective transition. In the absence of this transition, there is a serious risk that working knowledge is lost requiring a significant investment of time and resources to bring currently functioning beamlines and end stations back online. However, overlap of projects requires a clear delineation of roles and responsibilities of the staff. To mitigate risk of any ambiguity in staff roles and associated work breakdown tasks, we have defined clear and distinct objectives for each project during this overlap period. The objectives of the NeXUS Development project are documented in its project plan and will not be altered by the O&M project. The objectives of the O&M project during this overlap period are to transfer knowledge to newly hired staff and to prepare the facility for the first user experiments. This preparation requires several administrative tasks, including hiring various support staff, formation of the User Committee (UC), releasing the first call for user proposals, recruiting the PRP, and scheduling the first user experiments. The personnel supported by the O&M project will rely on Development project personnel for information and knowledge transition. As Development tasks are completed, the O&M project staff responsibilities will grow as they assume full responsibility for subsystems, the system, and eventually the full facility to support the first users.

4.2. Co-investigator DiMauro, AccelNet-Design Award

"AccelNet-Design: Extreme Light in Space, Intensity, Time and Space(X-lites)" (Award 2201502) provided $250,000 to **Louis DiMauro** (Principal Investigator), William Graves, Jennifer Cross, Louise Willingale, and **L. Robert Baker** from July 1, 2022 to November 30, 2024. No publications have been produced under this award.

4.2.1. Intellectual Merit

This grant's major goals, related to intellectual merit, are to build a network-of-networks (X-lites) and apply the Science of Team Science (SciTS) to build on existing networks of researchers with shared interests in the development and application of extreme light. X-lites builds on technological advances and international investments in extreme light facilities. The X-lites network uses these facilities to link together both facility users and facility staff. X-lites has completed nearly all its planned work and laid a foundation for the full implementation of the network. The successful activities of this design project have resulted in a commitment from 10 networks in Europe, Canada, and the US to support and participate in X-lites. NeXUS is a founding member of the X-lites network-of-networks.

4.2.2. Broader Impacts

This grant's major goals, related to broader impacts, are to use this new network to support the next generation researcher training and skills development for conducting collaborative research. X-lites has hosted workshops and short courses on effective teaming, meetings of the research community to enable collaboration, and workshops on the potential role of X-lites. X-lites activities are designed to specifically engage early career and diverse researchers (i.e., diverse demographics, scientific specialties, and geographic locations) who represent the future of these fields.

4.3. Co-investigator Kawakami, MRI Award

"MRI: Acquisition of Helium Recovery Equipment for Time-Resolved ARPES at NSF-NeXUS" (Award 2320634) provided $158,268 to **Roland Kawakami** (Principal Investigator), **Louis DiMauro**, **L. Robert Baker**, Jyoti Katoch from September 1, 2023 to August 31, 2026. No publications have been produced under this award.

4.3.1. Intellectual Merit

The project's major goals are to fund the acquisition of an ultralow temperature refrigerator for cooling samples down to a temperature of 10 K at the NSF-NeXUS mid-scale facility. Many of the most interesting phenomena in quantum materials occur at these very low temperatures, so this is a critical component for enabling a broad range of experiments. This project brings together a group of leading scientists in two-dimensional materials, chiral materials, magnetic materials, and topological materials, who are part of the first experiments and initial user base. The project team has completed an analysis of alternatives for the equipment, selected a vendor, and initiated the purchase of the major, long-lead equipment. We anticipate installation of the equipment in 2025.

4.3.2. Broader Impacts

The project's major goals are to support education and outreach activities that highlight these advanced instruments, their scientific value, and societal impacts to audiences ranging from researchers in adjacent disciplines to graduate and undergraduate students. The instruments in the NeXUS facility are open to users to propose research on a competitive basis, and the funded equipment will support those users and, therefore, advance the broad research community.

5. Proposed Work

5.1. User Experience

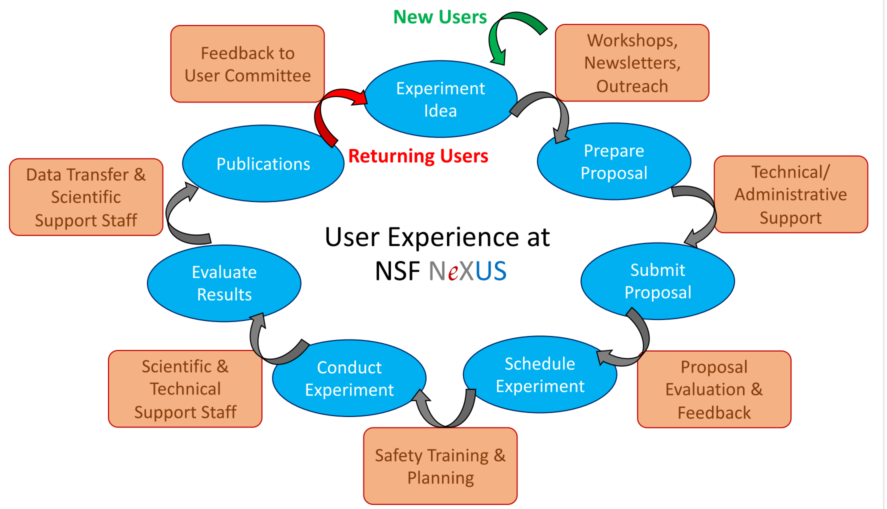

Figure 9. Schematic depiction of the user experience at NeXUS. Blue ovals represent steps taken by users to conceive, propose, perform, and evaluate an experiment. Orange rectangles represent support provided by NeXUS staff.

The central goal of NeXUS O&M is building and maintaining a NeXUS research ecosystem. The interaction between NeXUS and users is the foundation of this ecosystem, and Figure 9 depicts the cooperative cycle for users to learn about NeXUS; conceive potential experiments; and then propose, plan, execute, and evaluate an experiment. NeXUS staff and PIs will support each step of this process. As depicted, a successful ecosystem will encourage users to return with additional experiments and will welcome new users in a cycle that will continuously grow the user base.

5.2. Organizational Structure

As shown in Figure 3, the NeXUS facility is one only of the needed components for a thriving ecosystem ecosystem serving the scientific community. The project leadership, staff, sponsor, users, and host university also play critical roles, and Figure 10 depicts how these stakeholders will work together. This organizational structure has been designed based on feedback from the user workshops, guidance from the External Advisory Board (EAB), and evaluation of best practices in facility management. As shown, this structure includes layers of support from the NeXUS team at Ohio State (blue), engagement and feedback from advisory boards and facility users (green), and oversite and support from the sponsor (red). Each of these groups have roles in governance, administration, and operation that are described in more detail in Section 5.3. To realize this structure, the NeXUS leadership (Section 5.4) will hire staff (Section 5.5) and form advisory boards (Section 5.6), and the benefit of this structure will be the creation of a support infrastructure around the NeXUS facility that will enable transformative rather than incremental advances in ultrafast science in a way that is accessible to the entire community.

5.3. Major Tasks

To fulfill the vision of NeXUS as a scientific ecosystem, we will carry out nine major tasks to ensure successful O&M from the perspective of the end user:

1. **Governance:** The NeXUS Director, with the help of the Deputy Director, EAB, UC, and Facility Manager, will oversee the facility, establish policies, and evaluate performance to ensure that NeXUS fulfills its obligations to the user community and to the NSF sponsor.
2. **Administration**: The NeXUS Manager, in consultation with the Director and Deputy Director, will oversee the facility processes and staff to accomplish its objectives. In this first period of O&M, hiring will be a critical administrative activity, and the Manager will take the lead to recruit, hire, on-board, and retain the required staff. Hiring decisions will be determined by the Director, Deputy Director, and Manager with evaluation input from co-PIs and staff.
3. **Communication**: A NeXUS administrative Coordinator will ensure that all facility stakeholders receive regular communications on the facility's activities and opportunities. Communication with the user community will include a website, a regular newsletter, press releases, and an annual user workshop. Communications will also include public outreach and engagement that supports the facility's objectives for community impact and development.
4. **Safety**: The Manager, in consultation with the staff and UC, will ensure that the NeXUS facility is operated safely. NeXUS safety policies are described in Section 5.9. These policies will be

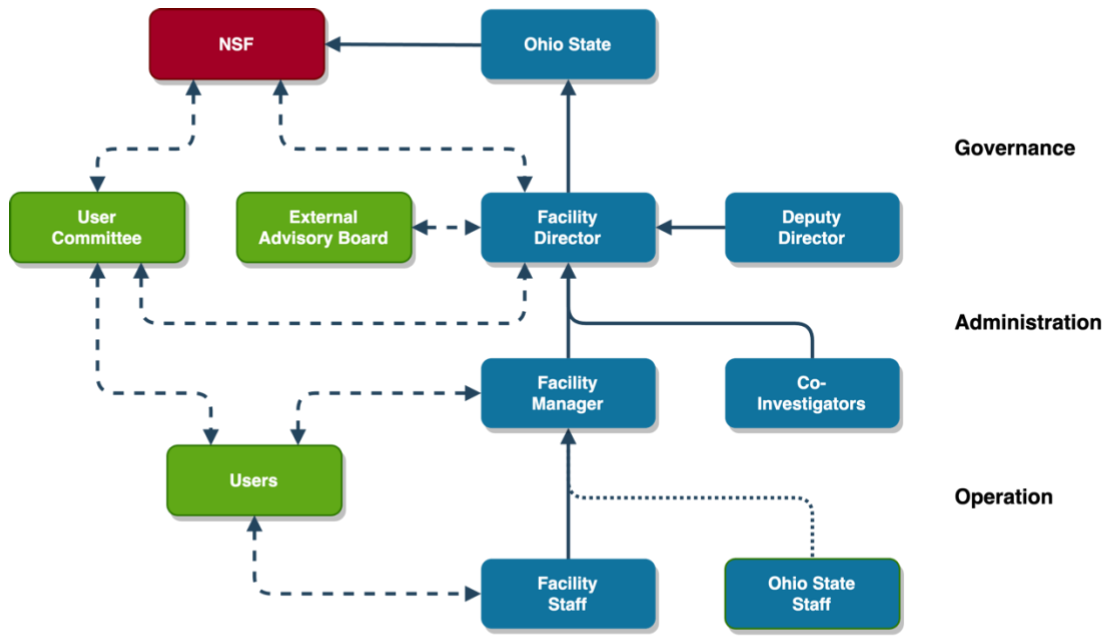

Figure 10. NeXUS organization chart. Blue rectangles indicate Ohio State, red indicates sponsor, and green indicates external. Solid lines are lines of reporting, dashed lines are lines of communication, and the dotted line is a line of indirect reporting.

continuously evaluated for effectiveness and updated when needed. The UC will provide written feedback on lab safety and lab culture.

5. **User Administration**: The Manager will administer the process of soliciting and evaluating user proposals for NeXUS experiments. A semi-annual call for proposals will be held (Section 5.7). The Manager will work with the UC to continuously evaluate and improve this process. The Manager will also ensure that users have the needed information and support to conduct their experiments.
6. **System Scheduling**: Based on the proposal process, the Manager will set a six-month schedule for facility use. The schedule will also account for system changeover, facility maintenance, and time designated for capability building (Section 5.8).
7. **User Experiments**: NeXUS System Scientists will support users to prepare for, execute, and analyze their planned experiments. A System Scientist with technical expertise on the experimental end station will be the technical point of contact to support each User Experiment. That scientist will work with the users and ensure that the system is used safely and effectively.
8. **Facility Maintenance**: The Manager, in consultation with the staff, will plan and oversee the facility and system maintenance required to meet user needs. Staff scientists and technicians will have responsibility for maintaining and verifying specific components and subsystems. Facility maintenance will incorporate a continuous assessment of processes for effectiveness and efficiency with the goal of increasing the time available for User Experiments.
9. **Capability Expansion**: The Director will select Capability Expansion priorities in consultation with the NeXUS co-PIs, EAB, and UC. These Capacity Expansion projects will expand facility capabilities, increase user productivity, and keep NeXUS at the cutting edge of ultrafast science. Each Capability Expansion will be managed as a project. A set of initial Capability Expansion priorities have been selected and are discussed in Section 6.

5.4. NeXUS Leadership

PI Baker will serve as **Facility Director**. The Facility Director will be accountable for all governance activities, including reporting to the sponsor, forming the EAB and UC, and securing the needed support from Ohio State. The Director will consult with these stakeholders to set the near term and long-term strategy for the facility. As one of the co-founders of NeXUS, DiMauro will serve as **Deputy Director** to provide continued support and ensure a smooth transition of project leadership. The Deputy Director will support the Facility Director to meet any of their responsibilities. The Deputy Director will step in on behalf of the Facility Director if necessary. Including the Director and Deputy Director, five **Co-investigators** have been selected to ensure the facility has the breadth and depth of expertise needed for a successful launch. Below is a summary of the expertise of each of the co-investigators as it pertains to NeXUS:

- **Robert Baker (PI & Director)**: Baker is a Professor of Chemistry and Biochemistry. His expertise is in ultrafast XUV transient absorption and transient reflection spectroscopy as an element-specific probe of charge and spin dynamics in catalytic materials. In addition to serving as Facility Director in O&M, he will support scientific applications of the XAS/XRS beamline and end station.
- **Louis DiMauro (co-PI, Deputy Director & Founding Co-Director)**: DiMauro is a Professor of Physics. His expertise is in attosecond electron dynamics and high harmonic generation. He will support scientific applications of the XAS/XRS beamline and the LIED/ATTO end station.
- **Jay Gupta (co-PI)**: Gupta is a Professor of Physics. His expertise is in atomic scale imaging of surfaces using scanning tunneling microscopy (STM). He has experience in time-resolved, element-resolved, and spin-resolved STM imaging. He will support scientific applications of the STM beamline and end station.
- **Roland Kawakami (co-PI)**: Kawakami is a Professor of Physics. His expertise is in growth and characterization of 2D semiconductors and other quantum materials. He has extensive experience with ARPES measurements. He will support scientific applications of the ARPES beamline and end station.
- **Claudia Turro (co-PI)**: Turro is a Professor of Chemistry and Biochemistry. Her expertise is in synthesis and ultrafast characterization of photochemical complexes, including applications in photocatalysis and photodynamic therapy. She will support scientific applications of the XAS/XRS end station with a focus on liquid sheet applications related to molecular photochemistry and biologically relevant systems.

The co-investigators will address three needs of the NeXUS ecosystem. First, they will mentor NeXUS research scientists and provide technical guidance on the implementation of experimental techniques to make optimal use of the NeXUS system. Second, they will pioneer the development of next-generation scientific capabilities to ensure that NeXUS stays at the cutting edge of ultrafast science. Third, they will act as ambassadors to the wide-ranging research communities within their respective disciplines to build a scientifically diverse user base.

Facility Manager Ronningen will be responsible for administering the facility. The Manager will supervise the facility staff and take responsibility for effective operation of the facility. The Manager will evaluate the performance of the facility against its planned schedule and budget and will prepare performance reports for the Director and other stakeholders. The Manager will oversee the user program and schedule experiment time for selected users. Ronningen is a Research Scientist in Electrical & Computer engineering with more than 10 years of industry experience managing system development projects and 6 years of Ohio State experience managing large-scale, multi-disciplinary, and multi-institution research initiatives.

5.5. NeXUS Staff

The NeXUS staff will be a mix of scientists, technicians, and administrative personnel all focused on meeting the needs of NeXUS users and supporting the development of the NeXUS ecosystem. The NeXUS leadership have evaluated the operational and maintenance needs of the facility and have set a target staffing level of four scientists, four technicians, and two coordinators. Each technical staff member will take responsibility for two major aspects of the facility and system as shown in Table 3. Each technical staff member will also expand their technical capabilities over time to provide cross-support and enable efficient operation. Most of these staff will be hired in the first year of operation, but some will be hired in years 2 or 3 to ensure there is time for effective training and to provide flexibility on areas of needed staff focus. As discussed further in

Table 3. Areas of primary and secondary responsibility for each NeXUS staff role.

Role	Primary Responsibility	Secondary Responsibility
Scientist A	Laser sources	HHG sources
Scientist B	XAS/XRS end station	LIED/ATTO end station
Scientist C	ARPES end station	Lab oversight
Scientist D	STM end station	Beamlines
Technician A	Laser operation	XAS/XRS+LIED/ATTO end stations
Technician B	Mechanical equipment	ARPES end station
Technician C	Electrical equipment	STM end station
Technician D	Control software	Data management

Section 5.8, our analysis has determined that the number and effectiveness of the staff will be the primary determinant of the facility's availability to users and, therefore, its ability to achieve its scientific and broader impacts. We have demonstrated the ability to attract highly qualified scientists via open searches during the development project confirming that NeXUS has made Ohio State an attractive destination for researchers working at the forefront of ultrafast science. NeXUS also has strong internal candidates for a number of these roles based on contributors to the successful development project. Consequently, we expect to be able to fill each of the required positions in a timely manner.

The four **System Scientists** are PhD-level scientists or engineers with demonstrated capability to design and execute experiments in their area of primary responsibility. The minimum number of System Scientists is fixed by the technical expertise needed to maintain and operate the highly specialized core equipment and scientific end stations of the NeXUS facility: 1) laser sources, 2) XAS/XRS and LIED/ATTO end stations, 3) ARPES end station, and 4) STM end station. This is reflected as the primary responsibilities for each of the four System Scientists in Table 3. These System Scientists will be the primary points of contact for users in the detailed planning and execution of their experiments. Their research expertise will enable them to work efficiently with users and provide guidance on the details of the NeXUS system. System Scientists will work directly with users to operate the system, troubleshoot their experiments, and evaluate data quality. System Scientists will remain experts in their field, will continue to lead and conduct scientific research, and will lead NeXUS Capability Expansion projects.

The four **Technicians** have undergraduate STEM degrees or equivalent work experience that enables them to operate and maintain the variety of equipment incorporated into the NeXUS system and facility. One technician will be hired to specialize in software development for system control and data management. The other three Technicians will be hired for their expertise with optical, electrical, and mechanical equipment. They will be trained by the System Scientists to operate the NeXUS system safely and effectively. While a minimum number of technicians is required to support basic lab maintenance, hiring and cross-training of lab-certified technicians to operate major equipment) represents a cost-effective method to increase user access by supporting extended hours of facility operation.

The **Coordinators** will support the facility leadership, staff, and users to schedule, complete, and track all administrative process. For example, a Coordinator will provide logistical support with travel and local accommodations, track user compliance with safety training, prepare regular reports and newsletters, and assist with organization of workshops. A Coordinator will manage all communications for the facility. As the number of users grows, we plan to hire a second Coordinator.

To support the facility and provide undergraduate students with professional development opportunities, we will hire 1-2 undergraduates per year to provide part-time support to the technical and/or administrative staff. Ohio State research facilities have found that undergraduates can provide effective assistance with routine tasks. These hires also provide a means of engaging students in the scientific and engineering capabilities of NeXUS.

As shown in Figure 10, **Ohio State Staff** outside of the NeXUS organization provide critical support to NeXUS and will be engaged regularly. Ohio State staff will maintain and administer university facilities, equipment, and processes that NeXUS staff and users rely on. The Manager will ensure effective communication and coordination with staff in closely related roles such as the building supervisor for Celeste Labs; the laser specialists in Environmental, Health, and Safety; and information technology specialists who support the network infrastructure in the NeXUS facility. NeXUS staff and users will also make use of other research facilities at Ohio State such as nanofabrication laboratories, electron microscopy facilities, and surface characterization facilities to prepare and characterize test samples as well as support equipment. Relevant Ohio State facilities that will be utilized to support of NeXUS user operations are described in the attached Facilities, Equipment, & Other Resources appendix.

5.6. Governance and Oversight

The NeXUS facility is a partnership between the NSF and Ohio State. Both organizations play critical roles in sustaining the NeXUS facility and ecosystem. Therefore, both organizations are stakeholders in the organization and play a role in its governance and oversight. NeXUS will also benefit from the guidance and oversight by a strong EAB and UC. As shown in Figure 10, the Facility Director is the primary point of contact for all governance.

Table 4. NeXUS External Advisory Board

Board Member	Institution	Expertise
Philip Bucksbaum (Chair)	Stanford University, SLAC	High Intensity Lasers Facility Management
David Awschalom	University of Chicago	Quantum Materials
Gregory Boebinger	Florida State University National High Magnetic Field Lab	Superconductivity Facility Management
Lin Chen	Northwestern University Argonne National Lab	Solar Photochemistry
Anthony Johnson	University of Maryland Center for Advanced Studies in Photonics Research	Material Photophysics
Roseanne Sension	University of Michigan	Physical Chemistry
Linda Young *(ex officio)*	University of Chicago Argonne National Lab	Chemical Physics Facility Management

The **NSF** provides NeXUS with financial support to operate as an open-access user facility. NSF has invested in the development of the NSF-NeXUS facility. During O&M, NSF's program officers and facility experts will provide oversite of NeXUS to ensure the facility meets its responsibility to the user community, effectively responds to risks and opportunities, and fulfills its mission as an open access facility designed to reshape the future of the US research landscape. The NSF will have direct lines of communication with both the Director and the User Committee to receive feedback on the performance of the facility.

The **Ohio State Office of Research** will have primary internal oversight of the NeXUS facility. The NeXUS facility will be organized as an Ohio State Multidisciplinary Center, reporting to the Office of Research. Designation as a Multidisciplinary Center makes NEXUS independent of specific departments and colleges, consistent with the facility's mission to support a broad array of disciplines. The Office of Research has reached agreements with specific Colleges and Departments to ensure NeXUS's ongoing usage of facilities and resources. This structure reflects the commitment of Ohio State leadership to ensure the success of this long-term NSF partnership. The Office of Research plans to form an Internal Advisory Board that will advise the Director and provide points of support across Ohio State's internal resources.

As shown in Figure 10, NeXUS will organize two external groups to support the governance of the facility. The **External Advisory Board** (EAB) is a board of experts, in scientific fields related to NeXUS and in research facility management. EAB members will be selected by the Director with approval of the cognizant NSF Program Officer. The EAB will support the Director to identify and mitigate risks associated with achieving the NeXUS facility's goals. The EAB plays a significant role in guiding the strategy of the facility to ensure it is providing value to the research community. The EAB will meet at least annually with the Director to review the facility status and activities, discuss plans (near term and long term), and provide feedback. The Director will support this annual meeting by providing the EAB with a written report in advance of the meeting. The EAB has the authority to issue independent reports to the NSF and the Ohio State Office of Research. An EAB has been formed during the NeXUS development project (see Table 4), and these members have agreed to serve on the EAB during O&M. The EAB will be expanded as needed to ensure the Director is receiving guidance from diverse experts.

The **User Committee** (UC) is a committee of potential or active users of the NeXUS facility. To ensure an independent voice on behalf of the user community, the UC reports directly to the NSF with a direct line of communication to the Facility Director. The chair of the UC is appointed by the Director with approval of the cognizant NSF program officer. The chair of the UC will serve as an ex officio member of the EAB. The UC will meet at least annually with the Director to provide feedback and advice on the operation of the facility and its development. The UC will be asked to provide feedback on each year's planned call for proposals. The UC will have the authority to contact NeXUS users to solicit input on their experiences and advice. The UC has the authority to issue independent reports to the NSF and Office of Research. NeXUS staff will provide administrative support to facilitate UC activities, and NeXUS funds have been set aside to support an annual user meeting organized by the UC. The UC has independent authority to establish its bylaws and elect members, but employees of Ohio State are not eligible for UC membership. Consistent with the vision of NeXUS as an ecosystem that will level the scientific playing field, the UC will ensure a strong voice to early career faculty and researchers from primarily undergraduate and minority serving institutions. Prof. Linda Young (Distinguished Fellow at Argonne National Lab and Professor of Physics at University of Chicago) currently serves as chair of the UC.

5.7. User Selection and Scheduling

The Facility Manager will administer the process of soliciting and evaluating user proposals for User Experiments. The process is illustrated in Figure 11. To ensure a transparent and fair proposal review process, a **Proposal Review Panel** (PRP) will be formed. The Manager, with the help of the Director, Deputy Director, and co-PIs, will recruit PRP members. Membership on the PRP will be for two-year terms. Employees of Ohio State are not eligible for PRP membership. Twice annually the PRP will provide written reviews of user proposals. Each user proposal will be reviewed by at least two panelists. Following reviews, the Manager will organize a meeting of the PRP to rank order proposals and guide facility scheduling. A call for proposals will be issued every 6 months. The call will remain relatively consistent, to support users, but will be refined and adjusted to meet the facility's goals and address concerns raised by the UC. The evaluation criteria will be:

- Scientific impact
- Ability to take advantage of NeXUS's unique capabilities
- Impact on early career researcher development (students, postdocs, and pre-tenure faculty)
- Feasibility (technical scope, timeline, safety)

Users selected for facility time through this process will not be charged for the use of the facility nor for staff support in preparing and executing their experiment. Users must adhere to the NeXUS user agreement that sets roles and responsibilities for work at the Facility. Users will be responsible for funding their team's travel to the facility and acquiring materials and supplies unique to their experiment (such as test samples). Early career researchers will be eligible for the fellowship described in Section 3.

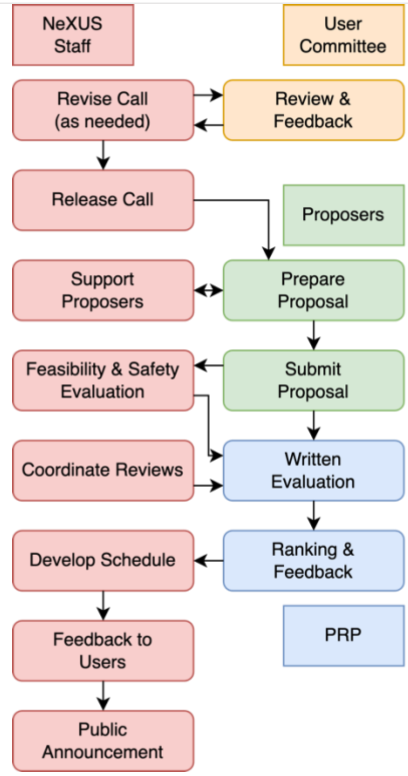

Figure 11. Process flow for requesting, receiving, and evaluating proposals for User Experiments.

5.8. Facility Utilization Plan

To meet the goals of NeXUS O&M, we will dedicate facility and staff time for User Experiments, Facility Maintenance, and Capability Expansion. To plan for an effective balance among these, we have investigated the operations of peer research facilities in the U.S. and Europe. Based on this research, we have set a target to operate the facility for 48 weeks per year, have 31 weeks (65%) available for User Experiments, and use the balance for Facility Maintenance and Capability Expansion. This access model is consistent with time allocation at other major light source facilities in the US and abroad as shown in Table 5.

In the first few years of operation, we expect that Facility Maintenance and preparation for User Experiments will require more time than in the long term. The NeXUS staff level will be ramping up over the first three years. Staff will be developing and improving maintenance processes, cross-training to support additional equipment, and developing more efficient software support tools. We are targeting to reach 65% User Experiment time by the end of year 3, when the full staff is in place. Even within this 65% (31 weeks), the number of users that can be supported annually will depend on the level of staff support. For example, with sufficient staffing and cross-training, one team of NeXUS staff can be preparing for subsequent user experiments, while another team supports the current users, reducing downtime between user groups. Pending a year 3 safety review, system operating protocols could expand to support simultaneous user experiments, using a second laser and/or beam splitting to have light available at several end stations. This process of experimental multiplexing has potential to significantly expand user access to NeXUS (Section 7).

The Facility Manager is responsible for setting, maintaining, and (when necessary) adjusting the schedule of planned User Experiments. Based on the PRP's recommendations, the Manager will schedule the experiments to balance efficiency and risks. In the first few years, before system maintenance risks are fully understood, the Manager will budget additional time to increase the likelihood of successful User

Table 5. Peer facilities used to support planning for NeXUS operation. All budgets are inflation adjusted to September 2023 dollars using the Consumer Price Index inflation calculator[70].

Facility	User Availability	Fee Structure	Annual O&M Budget	Sponsor Construction Budget	Relative O&M Budget
NSF-NeXUS target	15 hrs/5 days 31 wk/year	Free to academic users	$2.7M (Year 5)	$12.6M [71, 72]	22%
ChemMatCars @ APS	24 hrs/7 days* 30 wk/year	Free to academic users	$3.33M* [73]	$13.34M [74-76]	25%
ZEUS @ U. of Michigan	13 hrs/5 days 30 wk/year	Free to academic users	$4.5M [77]	$19.98M [78]	23%
ICR @ MagLAB	8 hrs/5 days 48 wk/year	Free to academic users	$2.13M [79]	$10.3M [80]	21%

* Note: Light source for ChemMatCars (Advanced Photon Source) supported by DOE personnel funded separate from NSF budget.

Experiments. As the staff gain experience and gather data, the scheduling will make more efficient use of the system and facility.

From discussions with potential users, we understand that different experiments are likely to benefit from different approaches to a facility workweek. We have heard from some potential users that it would be valuable for them to have extended hours on days when the system is working well. However, for NeXUS there will be a balance with safety and staffing. Our policies grant users 24/7 access to the laboratory and the control room. This access enables them to complete experimental preparations and data review at any time. However, users will not be permitted to run laser experiments independently due to safety risks. During the first three years of O&M, as staffing increases, user access time will increase, reaching 75 hours per week by year 3. In the early years of facility operation, user teams may be scheduled for multiple weeks as needed to acquire their target data.

5.9. Safety

During NeXUS development, the team completed a facility safety assessment, developed and documented facility safety procedures, reviewed those procedures with internal and external (safety officers at peer facilities) reviewers, and enacted the procedures to support verification and commissioning. The latest release of the NeXUS safety procedures is attached. These safety procedures will carry over to O&M, will be continuously evaluated, and will be updated when necessary. At the initiation of O&M, the Facility Manager will also be the Safety Lead, but this responsibility may be re-assigned to a technical staff member based on an evaluation of staff roles and responsibilities.

The hazard categories in the NeXUS lab are laser radiation (several Class 4 lasers), compressed gases, chemicals, and cryogenic liquids. To mitigate the laser hazards, the team implemented multiple engineering controls such as a separated control room, an airlock for safe entry, and laser-interlocked access controls. The safety procedures assign rights and responsibilities to personnel at the NeXUS facility, including users. Approved NeXUS users have independent access (24/7) to the NeXUS lab when the laser is not operating. When the laser is operating, users must be escorted into the lab by an approved NeXUS staff member.

5.10. Risk & Opportunity Management

During NeXUS development, the team has tracked project risks and opportunities, categorized them based on their probability and potential impact, and acted to mitigate the critical risks and take advantage of high-priority opportunities. This approach provided a valuable structure to the team's planning and to discussions with stakeholders. Therefore, the NeXUS team will continue to document facility risks/opportunities in a Risk and Opportunity Register. The NeXUS team has made an initial assessment of risk and opportunities for O&M. A tabulated summary of the initial O&M risk register is attached. The critical risks and high-priority opportunities identified in this assessment have guided the development of our plan for O&M. Examples from this assessment are:

- To mitigate the risk of a Safety Incident, the NeXUS team will emphasize safety in all interactions with users and will continuously evaluate our safety procedures.

- To mitigate risks related to the operation and maintenance of the NeXUS laser, NeXUS has purchased a commercial CARBIDE laser through an NSF supplement award. The CARBIDE laser will support some experiments and sustain operation if the NeXUS laser is undergoing maintenance.
- An opportunity exists to significantly increase user access by experimental multiplexing, i.e., performing multiple experiments simultaneously on separate beamlines. This could allow NeXUS to increase time for user experiments. This opportunity relies on sufficient staff support and the results of a year 3 safety evaluation.
- To mitigate risks of staff recruiting and retention, NeXUS is ensuring it can offer competitive salaries and benefits for the region and is implementing a management plan that emphasizes staff engagement and a positive workplace culture.
- To take advantage of opportunities for software unification, big data handling, and data standardization, NeXUS is prioritizing hiring a technician focused on software for system control, data collection, and data processing.

5.11. Data, Software, and Cyber

NeXUS has published a User Handbook that will be periodically reviewed and updated to address facility and user needs. This handbook establishes the rights and responsibilities of NeXUS staff and users. The User Handbook establishes the following intellectual property and data rights:

- Research data collected during a NeXUS experiment are the property of the users.
- Users are required to acknowledge NeXUS in any publication or presentation that uses these data.
- NeXUS staff who have contributed significantly to the planning, acquisition, or interpretation of data should be co-authors on resulting publications, and discussion of authorship guidelines will take place during experiment planning to set expectations.
- Users are allowed to collect data for proprietary purposes, but NeXUS must be informed of this intention at the time of the proposal, and NeXUS reserves the right to charge usage fees in these cases.

Additional information on the information technology and cybersecurity infrastructure that will support the NeXUS facility can be found in the attached Data Management Plan.

6. Capacity Building, Capability Expansion, and Life Cycle Planning

We will work to expand NeXUS's capacity to support user experiments and the variety of experimental capabilities available to meet our objective that NeXUS remains of high value beyond this first period of O&M. Capacity building refers to an increase in user groups and data collected, both enabled by sufficient staffing, process efficiency, and implementing best practices in facility O&M. In contrast, capability expansion refers to the in-house development by the NeXUS team to significantly expand the scientific experiments that NeXUS can support. Although capability expansion requires dedication of in-house facility time, which occurs at the expense of user access, a balanced combination of both capacity building and capability expansion is required to ensure that NeXUS fulfills its vision as an open access user facility with cutting edge capabilities. Accordingly, we have allocated 65% of facility time (31 wks/yr) to user experiments and the remaining 35% to a combination of in-house capability expansion projects and facility maintenance. This is consistent with best practices at other light sources and related user facilities as shown in Table 5. The specific priorities for capacity building and capability expansion will be under continuous evaluation, shaped by feedback from the user community, EAB, and UC, and driven by risks and opportunities. At the start of O&M, the NeXUS leadership has established initial priorities based on feedback from the first two user workshops and NSF site visit evaluations.

6.1. Capacity Building: Quality Management System

As a newly commissioned facility, NeXUS must demonstrate the ability to meet user expectations for reliable operation and availability. This is a key component to realize the vision of establishing a scientific ecosystem around the NeXUS facility. To ensure the success of this critical goal, the NeXUS team will invest focused effort to understand and improve O&M processes. NeXUS will adopt and adapt the principles of industrial quality management[81], incorporating them with the engineering and laboratory practices implemented during the development phase. Many connections are already in place (Table 6), and the Facility Manager will be responsible for formalizing three areas to support all NeXUS activities:

- **Process approach**: In line with the team's scientific and engineering backgrounds, NeXUS will take a process approach to completing its activities with the needed precision, accuracy, and repeatability for a scientific laboratory. Each User Experiment is likely to require the development of some new processes, but many processes will be executed repeatedly and, therefore, can be documented, evaluated, and continuously improved.

- **Improvement**: Continuous improvement is a central goal of the NeXUS Facility. This goal will be communicated to all staff, acted on, and made part of the culture of the NeXUS facility.
- **Evidence-based decision making**: To support decision making and establish evidence of improvement, the NeXUS team will define metrics and establish means of evaluating them. Initial facility and project metrics are discussed in Section 7. NeXUS will develop and track additional metrics to understand the technical details of the system and facility.

Table 6. Applicability of industrial quality management principles to NeXUS.

Quality Management Principle	For NeXUS
Customer Focus	Facility Users
Leadership	Director, Deputy Director, and Manager
Engagement of Stakeholders	NSF, Ohio State, UC, EAB
Engagement of Staff	Responsibility and authority for problem solving
Relationship Management	Major equipment vendors and Ohio State support staff

6.2. Capacity Building: Software Integration

The NeXUS system and subsystems were designed to support remote operation, with users in the Control Room safely separated from the hazards of the NeXUS lasers. The software to control each system has been developed by that system's design team. These separated control programs have been an efficient method to provide the needed capabilities, but they have introduced operational complexity. Staff will be using and troubleshooting multiple programs, decreasing the efficiency of operation and maintenance.

Entering O&M, the NeXUS team will hire a technician focused on software development who will develop and maintain the software for integrated NeXUS system control and data analysis. The NeXUS team has explored and identified several options of creating a unified interface. The software technician will design and implement a unified control scheme that improves the user experience and efficiency. The technician will work with the team to test, debug, and release this integrated software for facility users. The technician will use this advancement as a base to then take advantage of additional software-centered opportunities such as shared data processing tools and long-distance remote user control.

6.3. Capacity Building: Re-evaluation of Multiplexing

The NeXUS system design, three beamlines supported by two laser sources, enables two time-resolved experiments to run in parallel. However, the NeXUS team's analysis is that the safety risks of two high power laser beams and two distinct user groups during parallel experiments will require special care to mitigate. The current NeXUS safety procedures restrict operations to one time-resolved experiment at a time so that the safety risks are clearly understood and communicated to staff and users. Because multiplexing would significantly boost the facility value to users, the NEXUS team plans to re-evaluate this assessment after several years of operational experience. The Facility Manager will lead discussions and analyses to understand the risks, mitigations, and benefits of implementing multiplexing. It is the goal of the NeXUS team to eventually support experimental multiplexing, because of the significant benefit to the user community, pending the results of this year 3 safety evaluation.

6.4. Capability Expansion: OPA for ARPES

TR-ARPES is a unique experimental tool for probing the electronic structure of 2D material heterostructures and twisted systems. The ARPES beamline will enable scientists to measure time-resolved images over the entire Brillouin zone, but full realization of these capabilities requires a tunable ultrafast pump source. For example, a tunable wavelength pump source is required to explore the normally unoccupied electronic band structure of 2D materials. The NeXUS OPA will support tunable pumping at 100 kHz repetition rate, but most ARPES experiments require >1 MHz sampling rates to obtain high quality data without space charging. The NeXUS development project recently purchased a high repetition rate (1-5 MHz) OPA to support TR-ARPES measurements. This will significantly expand the capabilities of the ARPES beamline and end station. Co-PI Kawakami will lead the effort to integrate and demonstrate the functionality of this OPA such that these experiments can be available to NeXUS users.

6.5. Capability Expansion: Chemical Dynamics in Solution

On attosecond to few femtosecond timescales, much interest has been garnered in studying wave packet transitions through conical intersections, where pathway splitting determines the ultimate outcome of a reaction. However, to date the field works exclusively on isolated molecules in the gas phase due to the very high absorption of liquid phase samples and the comparably low photon flux of standard laboratory based HHG light sources. At NeXUS, similar measurements of photochemical complexes in their native solvation environment may be achieved by virtue of orders-of-magnitude higher average photon flux, which renders the high overall absorption of a liquid phase sample manageable. This class of experiments would provide transformative scientific impact by showing coherent wave packet motion through conical intersections for photochemical systems with catalytic and biological relevance. However, to achieve this will require the ability to measure time-resolved XUV spectra of solvated molecules in ultrathin liquid sheets. The instrumentation to achieve this liquid sheet exists at NeXUS, but the actual realization of these experiments will require the ability to operate stable liquid sheets for extended periods in the presence of high analyte concentrations. Experiments with a carefully selected, model system will be needed to demonstrate and verify the capabilities of this approach. This capability expansion project will be led by co-PI Turro. Turro's expertise in molecular photochemistry for photocatalysis and phototherapy applications as well as experience in synthesis of model systems qualifies her to lead this important capacity building effort at NeXUS.

6.6. Capability Expansion: Time- and Element-Resolved STM

A principal limitation of conventional STM is that the technique cannot directly identify atomic species without *a priori* knowledge of the sample and adsorbates being imaged. The element-specificity of core transitions excited by XUV or x-ray photons can address this limitation as recently demonstrated by Hla and co-workers using hard x-ray synchrotron radiation at Argonne National Lab[82]. In these measurements, the STM tip acts as a local detector for x-ray photoelectrons. The photoemission current then varies as the photon energy is tuned across core level transition energies, which provides the ability to spatially identify atomic species. The TR-STM beamline has been designed to enable these experiments. Going beyond what has been demonstrated at synchrotrons, NeXUS can combine the element-specificity and femtosecond time resolution of XUV pulses to probe time-resolved dynamics in quantum materials at specific atomic defect sites. However, these experiments will require the merger of two challenging techniques: time-resolved STM and element-resolved STM. This important capability expansion project will be led by co-PI Gupta, who has expertise and working experience in both techniques individually with the goal to soon make these experiments routinely accessible to NeXUS users.

6.7. NeXUS Life Cycle Planning Beyond 5 Years

One objective of the NeXUS team is for the facility to push the frontier of ultrafast science, including beyond the 5-year O&M plan described here. As a first-of-its-kind ultrafast laser user facility in the US, NeXUS has enormous potential to shape the future research landscape in ultrafast molecular and materials characterization. One step towards this objective is effective maintenance of the existing NeXUS equipment to ensure it remains useful as long as possible. The proposed staffing and budgeting account for this need, and the staff will continuously assess when more extensive maintenance, or even replacement, will be necessary. A second step towards this objective is planning for capability expansions on the 5-to-10-year time frame. Following our research ecosystem model, long-term facility expansion priorities will be defined by the community through feedback from user workshops, UC reports, EAB reports, and NSF site visits. With feedback from these external voices and leadership from our team of highly qualified and scientifically diverse co-PIs, our team will identify and respond to high impact opportunities to expand capabilities to meet this objective.

Initial feedback from the community has identified two potential projects for long-term expansion of NeXUS capabilities. The first is to extend NeXUS photon energies from XUV to soft x-rays allowing spectral access to the water window. Rapidly evolving technology in high average power thulium lasers indicate that robust kW-class laser systems at 2 μm wavelengths are becoming commercially available. Because the cutoff energy for HHG scales with λ^2, mid-IR driving lasers would enable NeXUS to produce attosecond soft x-ray pulses beyond 500 eV. This capability would be transformative for in situ studies of active catalytic and electrocatalytic interfaces as well as studies of biological complexes in their native solvation environments. The second expansion opportunity is time-resolved electron microscopy and diffraction. Ultrafast electron sources provide unprecedented insight into the structural dynamics of molecules and materials[83-86]. Combining NeXUS capabilities in x-ray spectroscopy with ultrafast electron microscopy and diffraction would provide a combination of measurements that will transform understanding of coupled electronic and structural dynamics in systems ranging from small molecules to complex materials. In consultation with the EAB, UC, and NSF, capability expansions such as these will ensure that NeXUS remains at the cutting edge far beyond the first 5 years of O&M.

7. Assessment and Evaluation

The quality management approach to NeXUS O&M described above sets the goal of continuous improvement and requires that we collect evidence to support decision making and assess performance. Data will be collected and compiled on an ongoing basis, and the Manager will share this information for internal assessment. NeXUS has set annual targets in Table 7.

Table 7. Facility targets against key metrics. Final column reflects benefit of experimental multiplexing at NeXUS.

By end of year:	1	2	3	4	5	Future
# Administrative Staff	2	2	3	3	3	4
# Scientists	3	4	4	4	4	4
# Lab Certified Technicians	1	2	2	3	3	5
User Time	50%	55%	65%	65%	65%	65%
User Workweek (hour)	40	67	67	75	75	75
Preparation (week/expt.)	2	1.5	1	0.5	0.5	0.5
Data Collection (week/expt.)	4	3	2	1.5	1.5	1.5
Annual Data Collection Hours	632	1220	1493	1788	1788	3060

The Director and Manager will prepare an annual report (for the Sponsor, EAB, UC, and Internal Advisory Board) that will include an assessment of facility performance tracked at least against:

- **User Time**: the fraction of operational time that the system is operating in support of User Experiments.
- **User Workweek**: the average hours in a scheduled user workweek in which the system is operational.
- **Experiment Preparation Time**: the time used to reconfigure the system in preparation for a user experiment.
- **Annual Data Hours**: the number of hours in a year in which the system is collecting user data.

NeXUS will ask the UC to provide an annual assessment of user feedback to identify additional areas of needed improvement. NeXUS will also evaluate metrics to measure the broader impact on the development of science, technology, and workforce.

The expansion of the staff and effective cross-training of staff is the key driver to improving all other metrics. Additional technical staff enable faster preparation of user experiments and longer workweeks while the users are on site. This combination is expected to increase the number of data collection hours by a factor of 2.8 between the first and last year of O&M. Also shown in Table 7 is a projected future jump in facility productivity that could come from implementing multiplexing (Section 6.3) during user workweeks. This is a significant opportunity but also carries risk that will be re-assessed during O&M. If the re-evaluation determines that the risks can be mitigated, multiplexing would also require an increase in NeXUS staff to enable parallel experiments. Therefore, Table 7 provides a forecast of the staffing changes that would be needed to take advantage of multiplexing.

We anticipate that these metrics will quantify how NeXUS O&M is amplifying the impact of this significant NSF investment. Through these assessments we hope to realize the initial vision for NeXUS as a facility that will shape the future of ultrafast science in the US by creating a new paradigm for putting cutting edge tools into the hands of the entire community with potential for transformative scientific impact. The user community, and their research, will achieve the ultimate potential of NeXUS.

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Documentation of Cost Share Commitments

Please review the enclosed form and insert your signature where designated below to confirm your agreed-upon cost share commitment for PI Robert Baker's NSF Mid-Scale Infrastructure renewal (NeXUS – National eXtreme Ultrafast Science Operation & Maintenance).

College of Arts and Sciences

Dr. Christopher Jaroniec

Signature: DocuSigned by: Christopher Jaroniec 8235FB162D1A403... Date Signed: 11/28/2023

Dr. Claudia Turro, Chemistry and Biochemistry

Signature: DocuSigned by: Claudia Turro E4C4E13C22064D2... Date Signed: 11/28/2023

Dr. Michael Poirier, Physics

Signature: DocuSigned by: Michael Guy Poirier 94FC9A29E04046C... Date Signed: 11/29/2023

College of Engineering

Dr. Andre Palmer

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Dr. Umit Ozkan, Chemical and Biomolecular Engineering

Signature: DocuSigned by: Ozkan, Umit S 3CCEC551EB4E4F1... Date Signed: 11/28/2023

ERIK

Dr. Dorota Grejner-Brzezinska, Office of Knowledge Enterprise ($95k annual support for 5 years), and Dr. Cynthia Carnes, Office of Research ($5k continued annual support to PI)

Signature: DocuSigned by: Dorota Grejner-Brzezinska DAC46DC3CBD5432... Date Signed: 11/28/2023

Signature: DocuSigned by: 5E11589432E54A4... Date Signed: 11/28/2023

THE OHIO STATE UNIVERSITY

ERIK COST SHARE REQUEST FORM

Instructions: The requesting PI should complete sections A and B below and send the form to their approving Associate Dean for Research (ADR), Dean, or designee along with a draft of their internal proposal budget and brief project narrative, summary, or abstract (e.g. existing draft proposal/proposal summary). The approving ADR, Dean, or designee then reviews the request and completes section C. Once all sections of the form are complete, the approving ADR, Dean, or designee should submit the completed form, internal proposal budget, and project summary for review via the OKE-managed **Research Funding and Awards portal**.

A. Team and Project Information

Internal Team Collaborators

PI Name	PI Department
L. Robert Baker	Chemistry and Biochemistry
Collaborator Name(s)	**Collaborator Department(s)**
Louis DiMauro	Physics
Jay Gupta	Physics
Roland Kawakami	Physics
Claudia Turro	Chemistry and Biochemistry

Project Title: National eXtreme Ultrafast Science (NeXUS) Operation & Maintenance

Proposal Sponsor: National Science Foundation

Link to Solicitation or Guidance: Unsolicited proposal (see NSF PAPPG, https://new.nsf.gov/policies/pappg/23-1)

Proposal Type: New

Submission Deadline: Nov. 27, 2023

B. Committed Cost Share Summary

Is cost share mandatory based on sponsor guidance? ☐ Yes, cost share is mandatory based on sponsor guidance. ☑ No, cost share is not mandatory based on sponsor guidance.

If cost share is not mandatory, please provide a detailed justification below as to why a cost share component has been added to this proposal. If the solicitation indicates cost share is not required, but that this type of institutional commitment will be considered as a factor in proposal evaluation, please direct reviewers to the page/section in the solicitation that contains this information.

The unique capabilities and international visibility of NeXUS are establishing The Ohio State University as a global leader in ultrafast science. As a national facility, NeXUS will enhance the research mission of faculty and staff across the university as well as establish OSU as a center of international collaboration in fields spanning chemistry, physics, materials science, and engineering. This is a request for non-disclosed, voluntary cost share needed to ensure the success of this project, which NSF views as a partnership with Ohio State.

Cost Share Table Instructions: In Column A, list the source of all existing internal cost share commitments (College, Department, Center, PI, etc.). Include the request being made of ERIK in the final row(s) of the table. For each entry use the drop down list in Column B to identify whether the source is cash or in-kind, and place the amount committed by year in Columns C-G, rounding to the nearest dollar. Select the budget category for each item from the drop down list in Column I.

A. Source	B. Cash/In-kind	C. Year 1	D. Year 2	E. Year 3	F. Year 4	G. Year 5	H. Total	I. Budget Category
College of Arts and Sciences	Cash	$ 100000	$ 100000	$ 100000	$ 100000	$ 100000	$ 500000	Personnel (Salary + Fringe)
Department of Chemistry & Biochemistry	Cash	$ 50000	$ 50000	$ 50000	$ 50000	$ 50000	$ 250000	Personnel (Salary + Fringe)
Department of Physics	Cash	$ 50000	$ 50000	$ 50000	$ 50000	$ 50000	$ 250000	Personnel (Salary + Fringe)
College of Engineering	Cash	$ 15000	$ 15000	$ 15000	$ 15000	$ 15000	$ 75000	Personnel (Salary + Fringe)
Department of Materials Science & Engine	Cash	$ 5000	$ 5000	$ 5000	$ 5000	$ 5000	$ 25000	Personnel (Salary + Fringe)
College of Arts and Sciences	In-kind	$ 61020	$ 61020	$ 61020	$ 61020	$ 61020	$ 305100	Other (please describe below)
Department of Chemistry & Biochemistry	In-kind	$ 86340	$ 36340	$ 36340	$ 36340	$ 36340	$ 231700	Other (please describe below)
Department of Physics	In-kind	$ 50000	$	$	$	$	$ 50000	Other (please describe below)
Department of Electrical & Computer Engir	Cash	$ 5000	$ 5000	$ 5000	$ 5000	$ 5000	$ 25000	Personnel (Salary + Fringe)
Department of Chemical & Biomolecular E	Cash	$ 5000	$ 5000	$ 5000	$ 5000	$ 5000	$ 25000	Personnel (Salary + Fringe)
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
		$	$	$	$	$	$ 0	
ERIK	Cash	$ 100000	$ 100000	$ 100000	$ 100000	$ 100000	$ 500000	Personnel (Salary + Fringe)
TOTAL		$ 527360	$ 427360	$ 427360	$ 427360	$ 427360	$ 2236800	

Please provide a brief narrative that describes the nature of each cost share commitment listed above, and what you are asking ERIK to support.

Description of cash contributions:
Director's administrative salary attachment: 15% base salary + fringe, estimated $28396/year
Administrative support: 25% admin base salary + fringe, estimated $20340/year
Facility manager: 10% base salary + fringe, estimated $17628/year
Research scientists: 25% base salary + fringe, estimated $171195/year
Materials, supplies, and equipment to support in-house research: estimated $92441/year

Description of in-kind contributions:
Director's teaching release (1 semester per year): CBC, estimated $16000/year
ASC Machine shop support (1 machinist at 50% FTE devoted to NeXUS), ASC, estimated $[illegible]/year

***If third party cost-share is being committed, please provide details in the text box below.**

N/A

C. Cost Share Request for OKE Review and Approval (to be completed by ADR, Dean, or designee)

Total cost share amount requested from ERIK	$ 500000

Which of the following eligibility boxes apply to this proposal?

- [x] The proposal supports multidisciplinary, cross-unit research from more than one school or college.
- [x] The proposal is for research equipment or facility renovation that will benefit multiple investigators from multiple schools/colleges.

Please summarize the College's cost share request to ERIK and provide a brief rationale for the need for central support.

The unique capabilities and international visibility of NeXUS are establishing The Ohio State University as a global leader in ultrafast science. As a national facility, NeXUS will enhance the research mission of faculty and staff across the university as well as establish OSU as a center of international collaboration in fields spanning chemistry, physics, materials science, and engineering. This is a request for non-disclosed, voluntary cost share needed to ensure the success of this project, which NSF views as a partnership with Ohio State.

I certify that I have reviewed the attached documents and that the cost-share identified as committed from all sources has been verified.

- [x] Yes, I have reviewed and verified the contents of the attached request.
- [ ] No, I have not reviewed and verified the contents of the attached request.

After Sections A, B, and C of this Cost Share Request form are complete, the college's authorized submitter should submit this form, along with the PI-provided internal proposal budget and brief project narrative/summary/abstract, via the OKE-administered Research Funding and Awards portal (3 documents). The authorized submitter will receive an e-mail notification of successful submission.

THE OHIO STATE UNIVERSITY

Enterprise for Research, Innovation and Knowledge

University Square South
15 East 15th Avenue
Columbus, OH 43201
erik.osu.edu

Peter J. Mohler, PhD
Executive Vice President
mohler.94@osu.edu

February 16, 2024

Fábio Leite, PhD
Chair, Council on Academic Affairs
Associate Professor, Lima Campus

W. Randy Smith, PhD
Vice Chair, Council on Academic Affairs
Vice Provost for Academic Programs

Dear Dr. Leite and Dr. Smith:

We are writing to express the strong support of the Enterprise for Research, Innovation and Knowledge (ERIK) for the proposal to designate the National eXtreme Ultrafast Science (NeXUS) Facility as a University Center at The Ohio State University. NeXUS is a first-of-its kind ultrafast laser facility in the United States. The unique capabilities and international visibility of this facility are establishing Ohio State as a global leader in ultrafast science. Construction of the NeXUS Facility is currently supported by a $10.5M infrastructure grant from NSF. A second proposal has been submitted to NSF and is currently under evaluation that will extend NSF support for Operations and Maintenance (O&M) of NeXUS as a national, open access user facility on Ohio State's campus. The combination of attosecond pulses, XUV and soft x-ray photon energies, and high repetition rate at NeXUS will enable measurements that currently cannot be made anywhere else in the United States. Accordingly, NeXUS is designed to fill a strategic gap in the US research infrastructure and forms the basis for a synergistic partnership between NSF and Ohio State, which establishes the University as a national leader in ultrafast, high intensity laser science.

The mission of NeXUS is inherently multidisciplinary and transcends the boundaries of traditional academic units. NeXUS has an obligation to serve the broader user community by providing access to unique-in-the-nation capabilities regardless of the user's institution or scientific discipline. By NSF mandate, NeXUS is to be a nationally accessible user facility whose primary objective is to increase the global competitiveness of the US research landscape. To protect this unique mission, ERIK will provide oversight of the NeXUS Facility as a University Center.

The attached proposal describes how the NeXUS facility aligns with and enhances the University's research strategy. As documented in this proposal as well as the attached MOU, NeXUS has strong support from multiple colleges, departments, and other University-level centers and institutes. Accordingly, NeXUS will enhance the research efforts of Ohio State faculty and staff across the University and will facilitate interdisciplinary collaborations of Ohio State faculty with the national and international research community who will visit Ohio State to use the NeXUS Facility. NeXUS will also enhance Ohio State's strong reputation in ultrafast science and continue to attract the best and brightest researchers worldwide to Ohio State.

Designation of NeXUS as a University Center is necessary to 1) enable NeXUS to fulfill its unique mission that transcends traditional research boundaries, 2) demonstrate to NSF a strong level of Ohio State support for this facility, which will be necessary to secure funding for long-term Operations & Maintenance of the facility, and 3) provide a direct line of communication and reporting between the NeXUS Facility director and ERIK for successful management and oversite of this interdisciplinary research facility.

Thank you very much for your support of this effort. We look forward to working together on this important project, which will benefit researchers from departments and colleges across the University as well as significantly strengthen Ohio State's role as a global leader in ultrafast science.

Sincerely,

DocuSigned by:
Peter Mohler
6B8C57AA84DC4A8...

Peter J. Mohler, PhD
Executive Vice President for Research, Innovation and Knowledge

cc: Amy Spellacy, Office of Research

THE OHIO STATE UNIVERSITY

College of Engineering

Center for Design and Manufacturing Excellence

1080 Carmack Road Suite 401
Columbus, OH 43210
614-292-6888 cdme@osu.edu
cdme.osu.edu

February 7, 2024

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs,

I am writing in support of the designation of NeXUS as an Ohio State Center. I am the Executive Director of the Center for Design and Manufacturing Excellence (CDME). CDME works with companies and researchers to translate new technologies into real-world, market-ready manufactured products. CDME supports technology translation by introducing companies to new technologies and providing hands-on training to students.

NeXUS is providing researchers with access to a new generation of laser technology. They will be the first facility in the United States to provide open access to these high power, high rep rate, laser systems. Their model of open access, including working with for-profit companies, provides an opportunity for companies to access and test this technology and its potential applications. CDME will work with NeXUS to share information about the unique capabilities and to explore potential projects or partnerships with companies. If these efforts are successful, the partnerships between NeXUS and CDME could extend further.

In summary, NeXUS is making a unique addition to Ohio State and our region's technical capabilities, and I look forward to working with the NeXUS team to share these capabilities with CDME affiliates.

Sincerely,

Nate Ames
Executive Director, CDME
OSU College of Engineering

THE OHIO STATE UNIVERSITY
SUSTAINABILITY INSTITUTE

Sustainability Institute
The Ohio State University
3018 Smith Lab
174 W. 18th Ave.
Columbus, OH 43210

614-247-4762 Phone

si.osu.edu

February 2, 2024

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

We are writing to express our support for designating NeXUS as an Ohio State University Center. The Sustainability Institute SI was founded in 2019 with the mission to support, lead, and integrate sustainability efforts across the university. One of our main goals is advancing research in sustainable technologies. At this time, over 300 faculty at Ohio State are affiliated with SI, including 29 core faculty from 18 different academic departments.

We are enthusiastic about the development and operations of the NeXUS facility on Ohio State campus. NeXUS will provide Ohio State researchers with access to advanced tools for studying fundamental processes such as those involved during solar energy conversion and storage. The ability to understand and control these processes is critical for developing new technologies necessary to support a sustainable future. Consequently, the unique capabilities available at NeXUS will be invaluable for supporting important ongoing research efforts of Ohio State faculty related to sustainable and renewable energy technologies.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation for innovative research and help us to continue to attract the best and brightest researchers worldwide to Ohio State. Accordingly, SI looks forward to future interactions with the NeXUS facility, and we strongly support its designation as an Ohio State University Center.

Best Regards,

Elena Irwin
Faculty Director Sustainability Institute
Distinguished University Professor
Department of Agricultural, Environmental, and Development Economics

Kate Bartter
Executive Director
Sustainability Institute

THE OHIO STATE UNIVERSITY
INSTITUTE FOR OPTICAL SCIENCE

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs

Dear Randy,

I am writing in support of the designation of NeXUS as an Ohio State Center. I am the Director of the Institute for Optical Science (IOS) and a Founding co-Director of the NeXUS implementation RI-1 project. IOS goals are the creation of an Ohio State community of multidisciplinary researchers in the optical sciences and the coordination of on-campus and regional centers to support research strengths in interdisciplinary photon science. The IOS accomplishes these goals through interdisciplinary workshops, seminars, and schools within and without the Ohio State community. We are also very proud that one of our members, Pierre Agostini, was the 2023 receiptent of the Nobel Prize in Physics.

IOS has been a strong supporter of NeXUS, contributing to its inception, providing early administrative support, helping to develop campus and government support, and sharing information about it among our members. IOS has had a strong working connection to NeXUS and will continue to work with them. In the last year, IOS won and led the X-lites project, supported by NSF's AccelNet program, to promote international collaboration in extreme light research. IOS has worked with researchers, facility directors, and facility staff from across North America and Europe to institute this new organization that will promote research in extreme light. NeXUS is one of the founding members of the X-lites network.

IOS members are excited and enthused that a center for ultrafast dynamics and cutting-edge lasers will be located at Ohio State. IOS members on campus and in the region are likely to submit proposals for using NeXUS and for collaborating with other users from around the world. NeXUS will raise Ohio State's profile as a global hub of research in optical dynamics, and IOS will support NeXUS by sharing information about it and helping to recruit talented optics researchers and students to Ohio State. IOS will also benefit from the presence of the NeXUS staff on campus. These staff will include researchers in lasers and laser applications, and I will seek to engage them as part of IOS to support their connection to the Ohio State research community and the regional community of optics researchers.

In summary, NeXUS is positioned to play a critical role in advancing optical science over the next decade, and I look forward to a continued synergistic collaboration between IOS and NeXUS.

Sincerely,

Lou DiMauro
IOS Director

THE OHIO STATE UNIVERSITY

Department of Chemistry and Biochemistry

Newman and Wolfrom Laboratory
100 West 18th Avenue
Columbus, OH 43210

614-247-7438

goldberger.4@osu.edu

February 6th, 2024

Dear Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

I am writing to express my strong support for designating NeXUS as an Ohio State University Center. I am a professor in the Department of Chemistry and Biochemistry as well as Director of the Center for Emergent Materials (CEM). CEM was founded at The Ohio State University in 2008 as an NSF Materials Research Science and Engineering Center (MRSEC). NSF support for this project has continued since that time and was most recently renewed in 2020 as a 6-year award for a total of $18M. Through this NSF project, CEM supports the research of more than 20 OSU faculty members spanning multiple departments and colleges. This interdisciplinary team allows CEM to address scientific challenges in materials science that cannot be solved by any single investigator.

Researchers within CEM are enthusiastic about the development and operations of the world-leading NeXUS facility on Ohio State campus. NeXUS will provide CEM faculty access to advanced tools for ultrafast materials characterization that cannot be performed anywhere else in the United States. These unique capabilities available through NeXUS will be extremely valuable for supporting the research mission of CEM.

In addition to supporting the efforts of CEM faculty, NeXUS will also enhance Ohio State's strong reputation for cutting edge research in ultrafast materials characterization and help continue to attract the best and brightest researchers worldwide to OSU. Accordingly, CEM faculty will continue to collaborate and interact closely with the NeXUS facility, and I strongly support its designation as an Ohio State University Center.

Sincerely,

Joshua Goldberger
Charles H. Kimberly Professor
Director, Center for Emergent Materials: An NSF MRSEC Center
Associate Editor, AAAS Science Advances

THE OHIO STATE UNIVERSITY

College of Arts and Sciences

186 University Hall
230 North Oval Mall
Columbus, OH 43210

614-292-1667 Phone
614-292-8666 Fax

artsandsciences.osu.edu

February 1, 2024

Re: ASC support letter for NeXUS

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

As the Associate Dean for Research and Creative Inquiry in the College of Arts and Sciences (ASC), I am writing to express my strong support for designating NeXUS as an Ohio State University Center. ASC is enthusiastic about the development and operations of the NeXUS facility on the Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers across the college access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of many faculty within the college.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, ASC has already provided significant voluntary cost share to support the early development of the NeXUS facility. The college has also agreed to provide continuing financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence and creative inquiry within ASC, and on behalf of the college I strongly support its designation as an Ohio State University Center.

Please do not hesitate to contact me at jaroniec.1@osu.edu with any questions or concerns.

Sincerely,

Christopher P. Jaroniec, Ph.D.
Associate Dean for Research and Creative Inquiry, College of Arts and Sciences
Arts and Sciences Distinguished Professor of Chemistry and Biochemistry

THE OHIO STATE UNIVERSITY

College of Arts and Sciences

Department of Physics
Associate Professor Ezekiel Johnston-Halperin

Physics Research Building
191 W. Woodruff Avenue
Columbus, OH 43210

614-247-4974 Phone
614-292-7557 Fax
Johnston-Halperin.1@osu.edu

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs,

We are writing in support of the designation of NeXUS as an Ohio State Center. We are the co-directors of the Center for Quantum Information Science and Engineering (CQISE). CQISE is focused on Ohio State's quantum research enterprise. CQISE brings together a multidisciplinary community of researchers across the university and throughout the region to advance fundamental quantum science, investigate the quantum-classical boundary, and explore applications with quantum advantage. The recognition of NeXUS as university center will support the research of Ohio State and global researchers in quantum information by providing world-leading tools for exploring the fundamental quantum properties of quantum-relevant materials.

The NeXUS facility will offer CQISE researchers access to time-resolved experiments at the attosecond to femtosecond time scale. CQISE researchers will have the opportunity to propose research using the NeXUS system and to collaborate with researchers from around the world who come to Ohio State to use NeXUS. CQISE faculty members are already involved in the development of the NeXUS facility and will continue to be involved as researchers.

The NeXUS facility will also enhance Ohio State's strong reputation for cutting edge research in time-resolved phenomena and optical experiments. Ohio State will increase its ability to attract faculty and students whose research will benefit from NeXUS, and recruitment is an area where CQISE and NeXUS will work together to attract the best and brightest. Both quantum experimentalists and theoreticians will have increased opportunities due to the NeXUS facility.

In summary, NeXUS will be a valuable addition to the Ohio State research ecosystem, and I believe it will open unique research opportunities for CQISE researchers.

Sincerely,

Ezekiel Johnston-Halperin
Professor, Department of Physics
The Ohio State University
e: ejh@mps.ohio-state.edu
v: (614) 247-4074

Ronald M. Reano
Professor, Department of Electrical and Computer Engineering
The Ohio State University
reano.1@osu.edu
614-247-7204

THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

Department of Materials Science and Engineering

2136 Fontana Laboratories
140 West 19th Avenue
Columbus, OH 43210
614-688-3050 Phone
mse.osu.edu

7 February 2024

Vice Provost Randy Smith, Professor Fabio Leite,
and Council on Academic Affairs:

As the Chair of the Department of Materials Science and Engineering, I am writing to express my strong support for designating NeXUS as an Ohio State University Center. The Materials Science and Engineering Department is enthusiastic about the development and operations of the NeXUS facility on Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers in our department access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of a number of faculty within our department.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, the Department of Materials Science and Engineering has agreed to provide financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence within the Department of Materials Science and Engineering, and I strongly support its designation as an Ohio State University Center.

Sincerely,

Michael J. Mills

Michael J. Mills
Taine G. McDougal Professor of Engineering
Department of Materials Science and Engineering
The Ohio State University

THE OHIO STATE UNIVERSITY

William G. Lowrie Department of Chemical
and Biomolecular Engineering

320 Koffolt Laboratories, CBEC
151 W. Woodruff Ave.
Columbus, OH 43210-1180
https://cbe.osu.edu
ozkan.1@osu.edu
614-292-6623

February 4, 2024

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

As the Chair of the Department of Chemical and Biomolecular Engineering, I am writing to express my strong support for designating NeXUS as an Ohio State University Center. The Chemical and Biomolecular Engineering Department is enthusiastic about the development and operations of the NeXUS facility on Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers in our department access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of several of faculty within our department.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, the Department of Chemical and Biomolecular Engineering has agreed to provide financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence within the Department of Chemical and Biomolecular Engineering, and I strongly support its designation as an Ohio State University Center.

Yours sincerely,

Umit S. Ozkan

Umit S. Ozkan
Distinguished University Professor
College of Engineering Distinguished Professor
Chair, William G. Lowrie Department of Chemical and Biomolecular Engineering

THE OHIO STATE UNIVERSITY

Department of Physics
Office of the Chair

1040 Physics Research Building
191 West Woodruff Avenue
Columbus, Ohio 43210-1117

614-292-2653 Phone
614-292-7557 Fax

physics.osu.edu

Thursday, February 15, 2024

RE: NeXUS

Dear Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

As the Chair of the Department of Physics, I am writing to express my full support for designating NeXUS as an Ohio State University Center. The Department of Physics has and continues to be extremely enthusiastic about the development and operations of the NeXUS facility on The Ohio State campus as an open access, national NSF user facility. This facility is an outstanding example of synergistic and collaborative efforts from faculty in the Department of Chemistry (2 PIs) and Biochemistry and in the Department of Physics (3 PIs). This amazing team with Prof. Baker's leadership has developed a facility that will provide researchers throughout the US access to the most advanced tools for ultrafast characterization of molecules and materials. Having the truly unique ultrafast capabilities of NeXUS here in our "backyard" is invaluable for supporting a range of ongoing research efforts on atoms, molecules, and materials within Physics. In addition, this facility has and continues to be key for recruiting top faculty members to the Department of Physics in the fields of Atomic, Molecular, and Optical Physics; Condensed Matter Physics; and Quantum Information Sciences.

NeXUS builds off and strengthens Ohio State's strong reputation in ultrafast optical science. For example, the attosecond technology that is central to the NeXUS facility leverages the foundational work in attosecond science that was awarded the 2023 Nobel Prize in Physics, which included Physics faculty member Prof. Pierre Agostini for his foundational work in this field. NeXUS as a University Center is critical for its successful operation as a National NSF Midscale user facility by providing the necessary independence for long term success. Furthermore, NeXUS as a center will be highly synergistic with other university efforts including the Institute of Optical Sciences and the Scarlet Laser Facility. Given the importance of NeXUS and how the Department of Physics was centrally involved with its development, we provided significant voluntary cost share to support the development stage of the NeXUS facility. Furthermore, the department has agreed to provide continuing financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is a spectacular facility that is a key part of defining OSU as the leader in ultrafast physics and is critical in supporting the mission of research excellence within the Department of Physics. I can't emphasize enough the importance of NeXUS and strongly support its designation as an Ohio State University Center.

Sincerely,

Michael G. Poirier
Professor and Chair
Department of Physics

THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS AND MANUFACTURING RESEARCH

E337 Scott Laboratory 201
West 19th Avenue
Columbus, OH 43210

February 8, 2024

Vice Provost Randy Smith
Office of Academic Affairs
University Square South
15 E. 15th Avenue
Columbus, OH 43201

Professor Fabio Leite
Department of Psychology
225 Psychology Building
1835 Neil Avenue
Columbus, OH 43210

Council on Academic Affairs
Office of Academic Affairs
University Square South
15 E. 15th Avenue
Columbus, OH 43201

Dear Profs. Smith, Leite and the CAA:

I am writing to strongly support the designation of NeXUS as a formal Ohio State Center. As the Associate Vice President for Research in the Office of Research, where I also serve as the Executive Director of the Institute for Materials and Manufacturing Research (IMR), this designation is critical for NeXUS to achieve its desired impact as a national center funded by NSF.

As you know, IMR is a well-established (since 2006) and vibrant university Center for many years and my role in leading the IMR has allowed me to observe, review and comment on a variety of centers as they develop. Currently, the IMR either manages and/or provides critical support to a number of centers, some of which were developed by the IMR. These include the Frontier Research Center with IIT-Bombay, the Center for Electron Microscopy and Analysis (CEMAS), the NSF-funded Center for Emergent Materials, the nascent Battery Cell Research and Development Center, the Intel-funded Center on Advanced Semiconductor Fabrication and Education (CAFE), and others that are more aligned as facility-based research centers, such as the Semiconductor Epitaxy and Analysis Lab (SEAL) and the Nanosystems Lab (NSL). Overall, the IMR supports the research of more than 250 faculty members across 10 colleges, with strategic research priorities across six signature areas that help to guide our strategic investments: electronic and photonic materials & devices, emergent materials, magnetic materials and phenomena, manufacturing and processing, materials characterization, and materials for energy & sustainability. Without a doubt, the recognition of NeXUS as a center will not only benefit the research of many of our members in new ways across these signature areas, but also will catalyze new areas given the nationally unique NeXUS capabilities.

The NeXUS facility will offer IMR researchers access to optics research that are first-of-their-kind in the US thanks to its unique capabilities. For example, IMR researchers in electronic and photonic materials will benefit from the NeXUS ARPES and STM capabilities, and IMR researchers in emergent materials and magnetic materials will benefit from the XAS/XRS capabilities. IMR researchers will have the opportunity to propose research using the NeXUS system and to collaborate with researchers from around the world who come to Ohio State to use NeXUS. Importantly, NeXUS capabilities are a perfect match for next generation semiconductor devices requiring extreme scaling, such as what is being envisioned with some of the new Intel fab capabilities being constructed in central Ohio where new materials for sub 5 nanometer and 2 nanometer device resolution is required.

The NeXUS facility will enhance Ohio State's strong reputation for cutting edge materials research in many ways that are only possible via access to the NeXUS center. It will therefore help in recruitment of new faculty across several colleges, and students will greatly benefit, beyond what is available nationally. The IMR will look forward to working with NeXUS for joint recruitment opportunities, and the novelty of NeXUS for IMR members will increase sponsor awareness of Ohio State's expanding research domains, allowing researchers and centers to synergistically attract sponsor support for large efforts from entities such as NSF, DoD, DoE and industry.

Finally, with IMR's experience in managing state of the art facilities as noted above, the role of staff researchers, engineers and technicians is vital to guarantee state of the art equipment performance, as expected by the NSF mid-scale program. I have observed how these staff become an essential part of the research community by collaborating with researchers and training students. NeXUS staff will play the same positive roles in the mission of the university.

In summary, the NeXUS Center will be a valuable addition to the Ohio State research ecosystem, and I look forward to expanded research opportunities for IMR members at NeXUS.

Sincerely,

Steven A. Ringel, Ph.D.
Associate Vice President for Research, Office of Research
Executive Director, Institute for Materials and Manufacturing Research (IMR)

Distinguished University Professor
Professor and Neal A. Smith Endowed Chair, Electrical and Computer Engineering

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THE OHIO STATE UNIVERSITY

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Academic Affairs

February 1, 2024

Memo: Support for NeXUS as am OSU Center
From: B. Shanker, Chair and Professor, ECE@OSU
To: Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs, ,

As the Chair of the Department of Electrical and Computer Engineering, I am writing to express my strong support for designating NeXUS as an Ohio State University Center. The Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs of Electrical and Computer Engineering is enthusiastic about the development and operations of the NeXUS facility on Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers in our department access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of a number of faculty within our department.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, the Department of Electrical and Computer Engineering has agreed to provide financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence within the Department of Electrical and Computer Engineering, and I strongly support its designation as an Ohio State University Center.

THE OHIO STATE UNIVERSITY

College of Arts and Sciences

Claudia Turro
Dr. Melvin L. Morris Endowed Professor and Department Chair

Department of Chemistry and Biochemistry
151 West Woodruff Avenue, Columbus, OH 43210
Phone: (614) 292-6723 Email: turro.1@osu.edu
http://chemistry.osu.edu

February 7, 2024

Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

As the Chair of the Department of Chemistry and Biochemistry, I am writing to express my strong support for designating NeXUS as an Ohio State University Center. The Chemistry and Biochemistry Department is enthusiastic about the development and operations of the NeXUS facility on Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers in our department access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of a number of faculty within our department.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, the Department of Chemistry and Biochemistry has already provided significant voluntary cost share to support the early development of the NeXUS facility. The department has also agreed to provide continuing financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence within the Department of Chemistry and Biochemistry, and I strongly support its designation as an Ohio State University Center.

Sincerely,

Claudia Turro
Dr. Melvin L. Morris Endowed Professor and Chair
Department of Chemistry and Biochemistry

THE OHIO STATE UNIVERSITY

Seth H. Weinberg, Ph.D.
Associate Dean for Research
College of Engineering
142 Hitchcock Hall
2070 Neil Avenue
The Ohio State University
Columbus, OH 43210
weinberg.147@osu.edu

January 23, 2023

Dear Vice Provost Randy Smith, Professor Fabio Leite, and Council on Academic Affairs:

As the Associate Dean for Research in the College of Engineering, I am writing to express my strong support for designating NeXUS as an Ohio State University Center. The College of Engineering is enthusiastic about the development and operations of the NeXUS facility on Ohio State campus as an open access, national NSF user facility. NeXUS will provide researchers across the college access to the most advanced tools for ultrafast characterization of molecules and materials currently available anywhere in the US. These unique capabilities will be invaluable for supporting important ongoing research efforts of many faculty within the college.

In addition to supporting the research efforts of OSU faculty, NeXUS will also enhance Ohio State's strong reputation in ultrafast optical science and help continue to attract the best and brightest researchers worldwide to OSU. To demonstrate its strong support to NeXUS, the College of Engineering has already provided significant voluntary cost share to support the early development of the NeXUS facility. The college has also agreed to provide continuing financial support for facility Operations & Maintenance as described in the attached MOU.

In summary, NeXUS is playing a critical role in supporting the mission of research excellence within the College of Engineering, and I strongly support its designation as an Ohio State University Center.

Sincerely,

Seth H. Weinberg, Ph.D.
Associate Dean for Research
College of Engineering
The Ohio State University