

Fellow Name: Katherine Annette Dynarski

Fellow ID: 2014184771

Project Title: Molybdenum dynamics in soil organic matter and implications for carbon storage

Start Date of Graduate Program: September 2013

Proposed Partner Agency: USGS

Host/Sponsoring Researchers: Steven Perakis

Proposed Dates and Duration of Internship: May 2017 – December 2018 (9 months)

Project Summary

Overview: The rock-derived micronutrient molybdenum (Mo) is essential to the enzyme system responsible for nitrogen (N) fixation, the pathway by which N is drawn from its inert atmospheric form into plant-available forms. N fixation is the dominant source of plant-available N and regulates ecosystem carbon (C) storage worldwide (Vitousek *et al.*, 2002), but can be limited by the availability of Mo in soils due to Mo's biochemical importance (Silvester, 1989; Barron *et al.*, 2009; Wurzbarger *et al.*, 2012). An understanding of Mo cycling and storage in soils is therefore critical in order to understand and predict terrestrial ecosystem function. Recent research indicates that Mo complexation by soil organic matter (SOM) contributes to the retention of bioavailable Mo in terrestrial ecosystems (Wichard *et al.*, 2009). N-fixing vegetation is known to accelerate SOM accumulation (Binkley, 2005), which can increase ecosystem Mo retention (Marks *et al.*, 2015). This suggests a possible mechanism for the coupling of the C, N, and Mo cycles wherein N fixation contributes to primary productivity and SOM accumulation; this SOM accumulation, in turn, enhances Mo retention and supports continued N fixation and forest productivity.

The proposed project examines coupled C-N-Mo biogeochemistry in Pacific Northwest temperate forests, using stands of N-fixing vegetation and non-fixing vegetation as a model system for understanding C-N-Mo linkages. N-fixing vegetation in these forests accelerates SOM accumulation and Mo retention, and should also have a higher demand for Mo than non-N fixing vegetation due to the critical biochemical role of Mo in N fixation; Mo availability has been found to limit symbiotic N fixation by lupine (Thorpe *et al.*, 2013) and red alder (Perakis, unpublished data) in this region. It follows that Mo retention and recycling should be elevated in soils with N-fixing vegetation compared to soils with non-N-fixing vegetation. However, this hypothesis has never been directly tested. By using N-fixing vegetation as a model system to understand Mo recycling and retention in terrestrial ecosystems, this work will elucidate fundamentals of C-N-Mo interactions on land, with practical implications for temperate forest N budgets, primary production, and C storage.

Intellectual Merit: Recent research demonstrates a connection between N fixation, SOM accumulation, and Mo retention, but this important biogeochemical interaction has yet to be studied in detail. This project will contribute to cross-disciplinary research linking trace element geochemistry to nutrient cycling and ecosystem function, with implications for N fertility and C storage in temperate forest ecosystems. This project also makes use of emerging stable isotopic tools to investigate coupled C-N-Mo cycling.

Broader Impacts: This work will contribute broadly to knowledge of temperate forest coupled nutrient cycling and C storage, which can be incorporated into global biogeochemical models to improve predictions of terrestrial C storage and climate change. My career goal is to be a principal investigator researching the terrestrial N cycle and links to other biogeochemical cycles; this collaboration will contribute to my professional development by enabling me to develop new laboratory and analytical skills as well as establish collaborations with experienced researchers in my field. Undergraduate students, particularly women and underrepresented minorities, will be included in this work as laboratory and field assistants. These students will receive scientific mentorship and learn valuable skills for research in biogeochemistry. As a graduate student at UC Davis, I have been involved in numerous mentorship programs that reach out to underrepresented and underprivileged students, including SEEDS, EnvironMentors, and Student and Landowner Education for Watershed Stewardship. I will continue to seek out opportunities for mentorship and community involvement during my time in Corvallis.

Project Description: This project will examine coupled C-N-Mo cycling in Pacific Northwest temperate forests, an important but not yet well-researched link between trace element geochemistry and terrestrial C storage. Symbiotic N fixation by actinorhizal trees in Pacific Northwest temperate forests contributes a substantial amount of ecosystem-available N, driving primary production, soil organic matter accumulation, and ecosystem C storage (Binkley, 2005). Recent research has demonstrated that tannins and tannin-like substances in soil organic matter can form complexes with the otherwise highly mobile molybdate (MoO_4^{2-}), contributing to Mo retention and bioavailability in forest soils (Wichard *et al.*, 2009; Marks *et al.*, 2015). This presents a mechanism for the coupling of the C, N, and Mo cycles in which symbiotic N fixation contributes to soil C accumulation, enhancing Mo retention and sustaining continued N fixation and forest productivity. The proposed project will examine how N-fixing trees influence Mo recycling and retention via organic matter production and Mo demand.

I propose to measure Mo abundance, distribution, and stable isotopic composition in soils and foliage from stands of N-fixing and non-N-fixing vegetation in a set of well-studied temperate forest plots in the Pacific Northwest. Soil cores will be sampled incrementally to a depth of 100 cm in pure stands of N-fixing trees and non-N-fixing trees. Plant tissue, including foliage, roots, and root nodules from N-fixing trees, will be collected, dried, and ground. A series of extractions will be performed on soil samples to assess distribution and potential bioavailability of Mo (Siebert *et al.*, 2015): exchangeable Mo (freely exchangeable in soil solution), metal-oxide associated Mo, and organic matter associated Mo. Mo concentrations in soil and foliage will be determined using inductively coupled plasma mass spectrometry (ICP-MS) and macronutrient (e.g. calcium) concentrations will be determined using inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Overall, I expect that Mo retention and recycling will be elevated in soils with N-fixing vegetation compared to soils with non-N-fixing vegetation; I hypothesize that there will be greater accumulation of Mo in soils in N-fixing stands vs. non-N-fixing stands, and that the majority of this Mo will be found associated with soil organic matter. I propose to examine Mo cycling in greater detail using stable isotope analysis of $\delta^{98}\text{Mo}$ in soil and vegetation by multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS), via ongoing collaborations between USGS and Oregon State University. Preliminary data indicates that although plant uptake of Mo does not cause significant isotopic fractionation, Mo adsorption to organic matter preferentially retains light Mo isotopes (King *et al.*, 2016). I hypothesize that Mo is recycled more rapidly when N-fixing trees are present due to their elevated Mo demand and expect that the $\delta^{98}\text{Mo}$ in plant tissue and in soil organic matter in stands of N-fixing trees will therefore have lighter values, reflecting fractionation associated with many cycles of Mo adsorption to organic matter followed by plant uptake. I expect to spend three months of the project conducting field sampling, and the next six months of the project preparing soil and vegetation samples for mass spectrometry analysis and conducting mass spectrometry analysis at the W.M. Keck Collaboratory for Plasma Spectrometry at Oregon State University.

As an early-career researcher in terrestrial biogeochemistry, I am excited to tackle questions about the fundamentals of ecosystem N cycling, especially questions linking trace element geochemistry to ecosystem N and C cycling. I am particularly interested in N fixation, and my dissertation research focuses on controls of free-living N fixation in terrestrial ecosystems, making this project a logical extension of my graduate work. I am currently preparing a manuscript for publication on Mo limitation of free-living N fixation and look forward to the opportunity to study interactions between Mo and N cycling in greater depth. I am

also excited by the opportunity to expand my research to symbiotic N fixation, as my previous thesis work has focused on free-living N fixation. My dissertation research makes use of N stable isotopic tools; this project will enable me to expand my isotopic skill set to the use of Mo stable isotopes. My undergraduate degree is in biochemistry, and I look forward to applying my skills and knowledge of biochemistry to examine Mo recycling and interaction with soil organic matter.

My career goal is to be a principal investigator and continue to research questions involving terrestrial N cycling and links to other biogeochemical cycles. This internship will allow me to gain additional N cycling research experience and work with mentors who are experts in my areas of research interest: Dr. Steven Perakis (USGS) is an expert in forest biogeochemistry, and works collaboratively with Dr. Julie Pett-Ridge (Oregon State University), an expert in Mo geochemistry. Working closely with Dr. Perakis and Dr. Pett-Ridge will contribute to my development as a researcher and allow me to build lasting professional collaborations. This internship will also allow me access to Dr. Perakis's temperate forest field sites, which have already been well-studied and provide an ideal natural laboratory in which to examine coupled C-N-Mo cycling. Additionally, I will be able to utilize the W.M. Keck Collaboratory for Plasma Spectrometry at Oregon State University for my measurements of Mo concentrations and Mo isotopes. Although I am familiar with the use of stable isotope data, I have not yet had the opportunity to operate the machinery myself. The Keck Collaboratory encourages users to conduct their own measurements and offers training on machine use. Having access to this facility will thus allow me to develop new skills in mass spectrometry that I will be able to draw upon in my later research career.

Professional Development Plan: My career goal is to be a principal investigator in the field of terrestrial biogeochemistry. I am particularly interested in N fixation, interactions between multiple nutrient cycles, and the use of stable isotopic tools to answer questions about N cycling. This project will enable me to continue to develop skills that will be essential in my future career, such as designing and conducting field experiments, performing chemical and isotopic analyses, performing data analysis, and writing peer-reviewed articles based on that research. This project will also help me develop new skills in working with Mo stable isotopes and the use of ICP-MS equipment. I look forward to establishing a professional collaboration with Steven Perakis and Julie Pett-Ridge through this internship. Their mentorship will contribute to my development as a researcher and I hope that it will lead to a continued productive research collaboration. This project is aligned with my previous publications, current dissertation work, and future research interests, so these are valuable collaborations for me to build. Furthermore, because I am interested in a career as a researcher with the U.S. Geological Survey, spending time in a USGS laboratory and building collaborations with USGS scientists is an important step in my professional development.

References Cited:

- Barron AR, Wurzburger N, Bellenger JP, Wright SJ, Kraepiel AM, Hedin LO. 2009.** Molybdenum limitation of asymbiotic nitrogen fixation in tropical forest soils. *Nature Geoscience* **2**: 42–45.
- Binkley D. 2005.** Chapter 8: How Nitrogen-Fixing Trees Change Soil Carbon. *Tree Species Effects on Soils: Implications for Global Change*: 155–164.
- King EK, Thompson A, Chadwick OA, Pett-ridge JC. 2016.** Molybdenum sources and isotopic composition during early stages of pedogenesis along a basaltic climate transect. *Chemical Geology* **445**: 54–67.
- Marks J a., Perakis SS, King EK, Pett-Ridge J. 2015.** Soil organic matter regulates molybdenum storage and mobility in forests. *Biogeochemistry* **125**: 167–183.
- Siebert C, Pett-ridge JC, Opfergelt S, Guicharnaud RA. 2015.** Molybdenum isotope fractionation in soils: Influence of redox conditions , organic matter, and atmospheric inputs. *Geochimica et Cosmochimica Acta* **162**: 1–24.
- Silvester W. 1989.** Molybdenum Limitation of Asymbiotic Nitrogen Fixation in Forests of Pacific Northwest America. *Soil Biology and Biochemistry* **21**: 283–289.
- Thorpe AS, Perakis S, Catricala C, Kaye TN. 2013.** Nutrient limitation of native and invasive N₂-fixing plants in northwest prairies. *PLoS ONE* **8**: e84593.
- Vitousek P, Cassman K, Cleveland CC, Crews TE, Field CB, Grimm NB, Howarth RW, Marino R, Martinelli LA, Rastetter EB, et al. 2002.** Towards an ecological understanding of biological nitrogen fixation. *Biogeochemistry* **57/58**: 1–45.
- Wichard T, Mishra B, Myneni SCB, Bellenger J-P, Kraepiel AML. 2009.** Storage and bioavailability of molybdenum in soils increased by organic matter complexation. *Nature Geoscience* **2**: 625–629.
- Wurzburger N, Bellenger JP, Kraepiel AM, Hedin LO. 2012.** Molybdenum and phosphorus interact to constrain asymbiotic nitrogen fixation in tropical forests. *PLoS One* **7**: e33710.

Budget and Budget Justification:

	Justification	Unit Cost	Quantity	Total Cost
Travel				
Airfare (Sacramento, CA to Corvallis, OR)	Cost of air travel from Katherine Dynarski's home institution (UC Davis) to the host institution in Corvallis, OR.	Estimated \$500 round trip	1 round trip	\$500
Equipment use fees				
Inductively coupled plasma mass spectrometer (ICP- MS) use at W.M. Keck Collaboratory	Measures concentrations of trace elements including Mo; ~60 samples can be measured in a day and ~120 samples are anticipated for this project.	\$600/day	2 days	\$1,200
Inductively coupled plasma atomic emission spectroscopy (ICP- AES) use at W.M. Keck Collaboratory	Measures concentrations of major elements such as Ca, Mg, and Na; ~60 samples can be measured in a day and ~120 samples are anticipated for this project.	\$400/day	2 days	\$800
Multicollector inductively coupled plasma mass spectrometer (MC- ICP-MS) use at W.M. Keck Collaboratory	Measures Mo stable isotope ratio; ~12 samples can be measured in a day and ~24 samples are anticipated for this project.	\$600/day	2 days	\$1,200
Materials and supplies				
Field costs	Travel to field sites in Oregon and supplies for collecting soil and plant tissue samples.	Estimated \$650 for project		\$650
Reagents and laboratory supplies	Reagents and laboratory supplies required for processing of soil and plant tissue samples, performing sequential extractions on soil samples.	Estimated \$650 for project		\$650
Total				\$5,000

Biographical sketch of the NSF Graduate Fellow:

Professional Preparation

Undergraduate Institution:	Villanova, PA, USA	Biochemistry	B.S., 2013
Villanova University			
Graduate Institution:	Davis, CA, USA	Soils &	Ph.D., 2018
University of California at Davis		Biogeochemistry	(anticipated)

Appointments

2013-present: *Doctoral Researcher, University of California at Davis, Davis, CA*

2009-2013: *Research Assistant, Villanova University, Villanova, PA*

Products

- Vile, M.A.; Wieder, R.K.; Živković, T.; Scott, K.D.; Vitt, D.H.; Hartsock, J.A.; Iosue, C.L.; Quinn, J.C.; Petix, M.; Fillingim, H.M.; Popma, J.M.A.; **Dynarski, K.A.**; Jackman, T.; Albright, C.M.; Wykoff, D.D. N₂-fixation by methanotrophs sustains carbon and nitrogen accumulation in pristine peatlands. *Biogeochemistry* (2014).
- **Dynarski, K.**; Mitchell, S.A.; Morford, S.L.; Houlton, B.Z. 2015 Bedrock nitrogen inputs support litter nitrogen fixation and temperate forest ecosystem fertility. American Geophysical Union Fall Meeting, December 14-18 2015 (Oral presentation).
- **Dynarski, K.**; Morford, S.L.; Houlton, B.Z. 2015. Role of bedrock nitrogen in regulating asymbiotic nitrogen fixation and plant tissue chemistry. Ecological Society of America Annual Meeting, August 9-14 2015 (Poster presentation).
- **Dynarski, K.**; Wieder, R.K.; Vile, M.A. 2013 Phosphorus limitation controls rates of biological N₂-fixation in boreal peatlands. American Geophysical Union Fall Meeting. San Francisco, CA, December 9-13 2013 (Poster presentation).
- **Dynarski, K.**; Wieder, R.K.; Vile, M.A. 2012. Nitrogen fixation in *Sphagnum* mosses in Canadian boreal peatlands: the role of molybdenum and phosphorous availability. BIOGEOMON: 7th International Symposium on Ecosystem Behavior. University of Maine, Northport, ME, July 15-19 2012 (Poster presentation).

Synergistic Activities

- NSF-GRFP Application Workshop Organizer, UC Davis, September 2014.
- “Genome Detectives” Workshop Organizer, Expanding Your Horizons UC Berkeley, March 2014, March 2015 (invited workshop), March 2016 (invited workshop).
- Ecological Science Educator/Facilitator, Insight Garden Program, Solano State Prison, 2014-present.
- Project Mentor/Advisor; Strategies for Ecology Education, Diversity and Sustainability (SEEDS); UC Davis Chapter, 2014-present.
- Ecological Restoration Mentor, Student & Landowner Education & Watershed Stewardship Program, 2013-present.

Collaborators and Other Affiliations

(i) Collaborators (15)

- Cara Albright (College of Engineering, Villanova University)
- Hope Fillingim (Department of Biology, Villanova University)
- Jeremy Hartsock (Department of Plant Sciences, Southern Illinois University)
- Christina Iosue (Department of Biology, Villanova University)
- Todd Jackman (Department of Biology, Villanova University)
- Scott Mitchell (former Department of Land Air & Water Resources, UC Davis)
- Scott Morford (Tetra Tech)
- Meaghan Petix (Institute for Applied Ecology)
- Jacqueline Popma (Department of Ecology & Evolutionary Biology, University of Michigan)
- James Quinn (Insight Environmental)
- Kimberli Scott (Department of Biology, Villanova University)
- Melanie Vile (Department of Geography and the Environment, Villanova University)
- Dennis Wykoff (Department of Biology, Villanova University)
- R. Kelman Wieder (Department of Biology, Villanova University)
- Tatjana Živković (Department of Geography, McGill University)

(ii) Doctoral research advisor (1)

- Benjamin Z. Houlton (Land Air & Water Resources/John Muir Institute for the Environment, UC Davis)

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE CERTIFICATIONS

NSF Graduate Research Fellowship Program Graduate Research Internship Program (GRIP)

Certification for Authorized Organizational Representative

By signing the Certification Pages, the Authorized Organizational Representative (AOR) is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, nondiscrimination, responsible conduct of research, and Federal tax obligations as set forth in the *NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG)*. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, §1001).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:

By signing the Certification Pages, the AOR is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization's expenditure of any funds under the award, in accordance with the organization's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

Instructions for Certification

1. By signing the Certification Pages the AOR is providing the certifications set out below.
2. The certification set out below is a material representation of fact upon which reliance was placed when the agency determined to award the grant. If it is later determined that the grantee knowingly rendered a false certification, or otherwise violates the requirements of the Drug-Free Workplace Act, the agency, in addition to any other remedies available to the Federal Government, may take action authorized under the [Drug-Free Workplace Act](#).

Certification Regarding Drug-Free Workplace Requirements

The grantee certifies that it will or will continue to provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing an ongoing drug-free awareness program to inform employees about --

(1) The dangers of drug abuse in the workplace;

- (2) The grantee's policy of maintaining a drug-free workplace;
 - (3) Any available drug counseling, rehabilitation and employee assistance programs; and
 - (4) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;
- (c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);
- (d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will --
- (1) Abide by the terms of the statement; and
 - (2) Notify the employer in writing of his or her conviction for a violation of a criminal drug statute occurring in the workplace, no later than five calendar days after such conviction;
- (e) Notifying the agency in writing, within 10 calendar days after receiving notice under subparagraph (d)(2) from an employee or otherwise receiving actual notice of such conviction.
- Employers of convicted employees must provide notice, including position title, to every grant officer or other designee on whose grant activity the convicted employee was working, unless the Federal agency has designated a central point for the receipt of such notices. Notice shall include the identification number(s) of each affected grant;
- (f) Taking one of the following actions, within 30 calendar days of receiving notice under subparagraph (d)(2), with respect to any employee who is so convicted--
- (1) Taking appropriate personnel action against such an employee, up to and including termination, consistent with the requirements of the Rehabilitation Act of 1973, as amended; or
 - (2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency;
- (g) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a), (b), (c), (d), (e) and (f).

Debarment and Suspension Certification

Instruction on Certification Regarding Debarment and Suspension

1. By signing the Certification Pages, the AOR is providing the certification set out below.
2. The inability of a person to provide the certification required below will not necessarily result in denial of participation in this covered transaction. The prospective participant shall submit an explanation of why it cannot provide the certification set out below. The certification or explanation will be considered in connection with the department or agency's determination whether to enter into this transaction. However, failure of the prospective primary participant to furnish a certification or an explanation shall disqualify such person from participation in this transaction.
3. The certification in this clause is any material representation of fact upon which reliance was placed when the department or agency determined to enter into this transaction. If it is later determined that the prospective primary participant knowingly rendered an erroneous certification, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.

4. The prospective primary participant shall provide immediate written notice to the department or agency to whom this proposal is submitted if at any time the prospective primary participant learns that its certification was erroneous when submitted or has become erroneous by reason of changed circumstances.
5. The terms covered transaction, debarred, suspended, ineligible, lower tier covered transaction, participant, person, primary covered transaction, principal, proposal, and voluntarily excluded, as used in this clause, have the meanings set out in the Definitions and Coverage sections of the rules implementing Executive Order 12549. You may contact the department or agency to which this proposal is being submitted for assistance in obtaining a copy of those regulations.
6. The prospective primary participant agrees by submitting this proposal that, should the proposed covered transaction be entered into, it shall not knowingly enter into any lower tier covered transaction with a person who is debarred, suspended, declared ineligible, or voluntarily excluded from participation in this covered transaction, unless authorized by the department or agency entering into this transaction.
7. The prospective primary participant further agrees by submitting this proposal that it will include the clause titled "Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transaction", provided by the department or agency entering into this covered transaction, without modification, in all lower tier covered transactions.
8. A participant in a covered transaction may rely upon a certification of a prospective participant in a lower tier covered transaction that it is not debarred, suspended, ineligible, or voluntarily excluded from the covered transaction, unless it knows that the certification is erroneous. A participant may decide the method and frequency by which it determines the eligibility of its principals. Each participant may, but is not required to, check the Nonprocurement List.
9. Nothing contained in the foregoing shall be construed to require establishment of a system of records in order to render in good faith the certification required by this clause. The knowledge and information of a participant is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.
10. Except for transactions authorized under paragraph 6 of these instructions, if a participant in a covered transaction knowingly enters into a lower tier covered transaction with a person who is suspended, debarred, ineligible, or voluntarily excluded from participation in this transaction, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.

Certification

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals: (a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from a covered transaction by any Federal department or agency; (b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property; (c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and (d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall include an explanation with this proposal.

Certification Regarding Nondiscrimination

Instructions for Nondiscrimination Certification

1. In accordance with NSF policy, by signing the Certification Pages, the AOR is providing the requisite Certification of Compliance with National Science Foundation Nondiscrimination Regulations and Policies. This Certification sets forth the nondiscrimination obligations with which all awardees must comply. These obligations also apply to subrecipients, subgrantees, and subcontractors under the award. The proposer therefore, shall obtain the NSF Nondiscrimination Certification from each organization that applies to be, or serves as a subrecipient, subgrantee or subcontractor under the award (for other than the provision of commercially available supplies, materials, equipment or general support services) prior to entering into the subaward arrangement.
2. The AOR shall provide immediate notice to the Foundation if at any time the proposer learns that its certification was erroneous when submitted, or has become erroneous by reason of changed circumstances.

Certification of Compliance with National Science Foundation Nondiscrimination Regulations and Policies

By signing the Certification Pages, the AOR hereby certifies that the organization will comply with Title VI of the Civil Rights Act of 1964 ([42 USC § 2000d](#)), Title IX of the Education Amendments of 1972 ([20 USC §§ 1681 et seq.](#)), the Rehabilitation Act of 1973 ([29 USC § 794](#)), the Age Discrimination Act of 1975 ([42 USC §§ 6101 et seq.](#)) and all regulations and policies issued by NSF pursuant to these statutes.

To that end, in accordance with the above-referenced nondiscrimination statutes, and NSF's implementing regulations and policies, no person in the United States shall, on the ground of race, color, national origin, sex, disability, or age, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Proposer receives Federal financial assistance from the Foundation; and **HEREBY CERTIFIES THAT** it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Proposer by the Foundation, this Certification shall obligate the Proposer, or in the case of any transfer of such property, the transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this Certification shall obligate the Proposer for the period during which it retains ownership or possession of the property. In all other cases, this Certification shall obligate the Proposer for the period during which the Federal financial assistance is extended to it by the Foundation.

THIS CERTIFICATION is given in consideration of and for the purpose of obtaining any and all Federal grants, cooperative agreements, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Proposer by the Foundation, including installment payments after such date on account of applications for Federal financial assistance which were approved before such date. The Proposer recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this Certification, and that the United States shall have the right to seek judicial enforcement of this Certification. This Certification is binding on the Proposer, its successors, transferees, and assignees.

By signing these certifications, I certify that the statements made herein are true and complete to the best of my knowledge and belief; and I agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

		
Name	Date	
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