

Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT)

PROGRAM SOLICITATION NSF 21-539

REPLACES DOCUMENT(S): NSF 20-537



National Science Foundation

Directorate for Engineering
Division of Electrical, Communications and Cyber Systems

Directorate for Computer and Information Science and Engineering
Division of Computer and Network Systems

Directorate for Mathematical and Physical Sciences
Division of Astronomical Sciences

Directorate for Geosciences
Division of Atmospheric and Geospace Sciences

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

March 05, 2021

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 20-1), which is effective for proposals submitted, or due, on or after June 1, 2020.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT)

Synopsis of Program:

The National Science Foundation's Directorates for Engineering (ENG), Computer and Information Science and Engineering (CISE), Mathematical & Physical Sciences (MPS), and Geosciences (GEO) are coordinating efforts to identify new concepts and ideas on Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT). A key aspect of the SWIFT program, now in its second year, is its focus on effective spectrum utilization and/or coexistence techniques, especially with passive uses, which have received less attention from researchers. Coexistence is when two or more applications use the same frequency band at the same time and/or at the same location, yet do not adversely affect one another. Coexistence is especially difficult when at least one of the spectrum users is passive, i.e., not transmitting any radio frequency (RF) energy. Examples of coexisting systems may include passive and active systems (e.g., radio astronomy and wireless broadband communication systems) or two active systems (e.g., weather radar and Wi-Fi). Breakthrough innovations are sought on both the wireless communication hardware and the algorithmic/protocol fronts through synergistic teamwork. The goal of these research projects may be the creation of new technology or significant enhancements to existing wireless infrastructure, with an aim to benefit society by improving spectrum utilization, beyond mere spectrum efficiency. The SWIFT program seeks to fund collaborative team research that transcends the traditional boundaries of individual disciplines.

SELECTED LIST OF ACRONYMS

AI	Artificial Intelligence
EARS	Enhancing Access to the Radio Spectrum
EESS	Earth Exploration-Satellite service
EM	Electromagnetic

IoT	Internet of Things
ITU	International Telecommunication Union
MICS	Medical Implant Communication System
NRDZ	National Radio Dynamic Zone
PAWR	Platform on Advanced Wireless Research
RAS	Radio Astronomy Service
RF	Radio Frequency
RFI	Radio Frequency Interference
RFID	Radio Frequency Identification Device
RR	Radio Regulations
SpecEES	Spectrum Efficiency, Energy Efficiency, and Security
UAS	Unmanned Aircraft Systems

Cognizant Program Officer(s):

Please note that the following information is current at the time of publishing. See program website for any updates to the points of contact.

- Mohammad Ali, telephone: (703) 292-4632, email: moali@nsf.gov
- Alexander Sprintson, telephone: (703) 292-8950, email: asprints@nsf.gov
- Zhengdao Wang, telephone: (703) 292-7823, email: zwang@nsf.gov
- Lawrence S. Goldberg, telephone: (703) 292-8339, email: lgoldber@nsf.gov
- Albert Z. Wang, telephone: (703) 292-7230, email: awang@nsf.gov
- Jonathan V. Williams, telephone: (703) 292-2455, email: jonwilli@nsf.gov
- Murat Torlak, telephone: (703) 292-7748, email: mtorlak@nsf.gov
- Bevin A. Zauderer, telephone: (703) 292-2428, email: bezauder@nsf.gov
- Lisa M. Winter, telephone: (703) 292-8519, email: lwinter@nsf.gov

Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):

- 47.041 --- Engineering
- 47.049 --- Mathematical and Physical Sciences
- 47.050 --- Geosciences
- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Standard Grant

Estimated Number of Awards: 12 to 16

Approximately 12-16 awards are anticipated, each up to \$750,000 total and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: \$12,000,000

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

The budget for a given proposal should be commensurate with the complexity of the proposed research.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.

Who May Serve as PI:

By the submission deadline, any PI, co-PI, or other senior project personnel must hold either:

- a tenured or tenure-track position, or
- a primary, full-time, paid appointment in a research or teaching position

at a US-based campus of an IHE eligible to submit to this solicitation (see above), with exceptions granted for family or medical leave, as determined by the submitting organization. Individuals with primary appointments at for-profit non-academic organizations, non-profit non-academic organizations, or at overseas branch campuses of US IHEs are not eligible.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may be listed as PI, co-PI, and/or senior personnel on only one proposal submitted in response to this solicitation. In the event that an individual exceeds this limit, only the first proposal received before the deadline will be accepted, and the remainder will be returned without review.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
 - Full Proposals submitted via FastLane: *NSF Proposal and Award Policies and Procedures Guide (PAPPG)* guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
 - Full Proposals submitted via Research.gov: *NSF Proposal and Award Policies and Procedures Guide (PAPPG)* guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
 - Full Proposals submitted via Grants.gov: *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov* guidelines apply (Note: The *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide).

B. Budgetary Information

- **Cost Sharing Requirements:**

Inclusion of voluntary committed cost sharing is prohibited.
- **Indirect Cost (F&A) Limitations:**

Not Applicable
- **Other Budgetary Limitations:**

Not Applicable

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

March 05, 2021

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review criteria apply. Please see the full text of this solicitation for further information.

Award Administration Information

Award Conditions:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

The dramatic growth in use of wireless technologies has benefited society in many sectors including commerce, transportation, health, science, and defense. However, the proliferation of new application technologies, such as the Internet of Things (IoT), Unmanned Aircraft Systems (UAS), radars for transportation and motion sensing, as well as new infrastructure technologies such as broadband wireless, has brought forth new challenges that must be addressed in light of the demand on the wireless spectrum placed by such applications. The electromagnetic (EM) spectrum is limited and must be appropriately shared among all wireless systems and applications, including both active and passive uses. The increasing demand for spectrum is largely driven by commercial services such as mobile broadband wireless access. At the same time, passive uses of spectrum including radio astronomy service (RAS) and atmospheric and geospace science under the earth exploration-satellite service (EESS) as well as critical but non-commercial active uses such as weather radar and the Global Positioning System (GPS) need to be preserved. These services are bound by physical constraints that prevent any relocation of spectrum, and hence the operations of these services have to be protected.

The effective utilization and sharing of spectrum, a limited resource, is very important, as highlighted in the October 2018 Presidential Memorandum [1] on "Developing a Sustainable Spectrum Strategy for America's Future" and May 2019 interagency response [2] led by the National Science and Technology Council's Wireless Spectrum Research & Development Interagency Working Group (WSRD IWG), titled "Research and Development Priorities for American Leadership in Wireless Communications."

NSF continues to provide support for basic research on wireless communications and networking via its core and interdisciplinary program funding mechanisms. Past and current NSF spectrum-related programs include Enhancing Access to the Radio Spectrum (EARS), Spectrum Efficiency, Energy Efficiency, and Security (SpecEES), and Platforms for Advanced Wireless Research (PAWR). In FY 2020 NSF launched a major new initiative called the [Spectrum Innovation Initiative \(SII\) Center program \(NSF 20-557\)](#) which is in clear synergy with SWIFT.

The key aspect of the SWIFT solicitation is a focus on effective spectrum utilization and/or coexistence, especially with passive uses. This will require substantial innovation in wireless technology. Research proposed under this solicitation must go beyond past programs that focused mainly on spectral efficiency (bits/sec/Hz) and energy efficiency (bits/Joule). Developing new methods or techniques enabling effective spectrum utilization and/or coexistence will enable wireless systems and networks to support the high performance (e.g., higher data-rates, lower latency) and dense deployments that will be needed by future applications operating in spectrally adjacent channels or in co-channel. Wireless research and development today require a focus on robust, reliable, and secure wireless systems and networks for the next generation networks and systems. Research focusing on novel efficient device design, advanced RF/analog hardware security, circuit and antenna design, communication theory, signal processing, new algorithms and protocols, machine learning etc. should come together to address the upcoming challenges facing wireless systems and networks. Research that will enable the above will likely provide immense societal benefits provided that the integrity of passive receive-only uses is also preserved.

Awareness of spectrum usage by existing critical passive and active systems and their associated requirements is necessary to develop new technologies for effective future spectrum sharing. Spectrum innovations may focus on any part of the EM spectrum from kHz to terahertz (THz). Wireless application domains include future mobile broadband, IoT, CubeSat, UAS communications, satellite/space communications, remote sensors, sensing systems for intelligent infrastructure, wearable/implantable medical devices, radio astronomy, automotive radar, weather radar, and aircraft communications etc.

[1] <https://www.whitehouse.gov/presidential-actions/presidential-memorandum-developing-sustainable-spectrum-strategy-americas-future/>

[2] <https://www.whitehouse.gov/wp-content/uploads/2019/05/Research-and-Development-Priorities-for-American-Leadership-in-Wireless-Communications-Report-May-2019.pdf>

II. PROGRAM DESCRIPTION

New applications that rely on utilizing more wireless spectrum promise significant societal and economic benefits, but at the same time, many commercial and military wireless devices and systems, radio astronomy observatories, and weather radar systems need to operate in quiet EM environments or without interference from other signals. The demands on the spectrum often threaten the operations of such existing technologies that offer critical service to society. Innovation in spectrum use and management provides a means to ensure that the spectrum resources are utilized in a manner that benefits all applications, both current and emergent, including those operating at higher frequencies (such as mmWave and THz).

As spectrum becomes more congested, future wireless systems and passive users will be required to share spectrum and/or be very tightly packed together. In order to enable these kinds of deployments, innovations are sought on (i) transmitter technologies, such as filters, antennas, switches and amplifiers that must ensure high in-band performance along with ultra-low spurious out-of-band emission, (ii) receiver technologies that must show significant advancement to ensure that receivers can function in the presence of strong interference, both co-channel and adjacent channel, (iii) physical layer (PHY) and medium access control (MAC) protocols that are not constrained by existing standards (e.g. cellular and Wi-Fi), (iv) machine learning and AI techniques that allow effective spectrum sharing and access, and (v) spectrum coexistence methods that go beyond the standard sensing and database management methods used today. SWIFT expects hardware researchers to collaborate with communication theory/signal processing and system/network researchers to make the most meaningful impact.

Significant advances in communication theory, networks, and protocol research are needed to allow effective coordination and maximum utilization of the spectrum. The development of innovative methods to utilize vast amounts of data and allow smart decision making will likely play an important role, which could be considered within an artificial intelligence (AI) framework to ensure effective spectrum utilization and coordination.

All proposals submitted in response to the SWIFT program must address at least one of the two **primary challenges** from Group A below. In addition, proposals must address one or more of the challenges listed in Group B or identify and address new challenge(s):

Group A: Effective Spectrum Utilization and/or Coexistence

Spectrum Utilization – Innovations are sought on ways to improve the spectrum utilization efficiency within frequency bands that are preallocated for wireless communications and networking. These may include, but are not limited to, massive multiple-input multiple-output antenna arrays, advanced signal processing for communications and networking, novel and efficient error-control coding, joint source-channel coding, passive and active intelligent surfaces, combined model-based and data-based transceiver designs and optimization, tradeoff between capacity and complexity, and cloud based radio signal processing.

Spectrum Coexistence - Although the growing demands on the wireless spectrum are mainly driven by commercial active uses (e.g., mobile broadband wireless), critical passive uses (e.g., radio astronomy, atmospheric and geospace sciences, and climatological observations) as well as critical active uses (e.g., weather radar and GPS) also need consideration as systems that will share the same or adjacent spectrum bands are deployed. Current means of spectrum sharing are limited to sensing and database management around mostly active users; exploring new spectrum utilization and sharing paradigms for bidirectional sharing with passive users such as radio-astronomy have largely remained unexplored. Proposals that intend to use specific frequency bands should demonstrate awareness of incumbent passive and active uses and address coexistence issues with these uses. Specifically:

- Proposers should articulate how their proposed efforts will ensure that the scarce EM spectrum will be effectively utilized while other uses are being protected through RFI excision, avoidance, and other methods. An alternative approach could be to develop new methods and techniques that allow co-channel or adjacent channel use of spectrum bands currently exclusively reserved for passive use such that passive users can continue to operate satisfactorily. Such methods should account for the fact that the interference thresholds for passive users are orders of magnitude lower than those of active users of spectrum.
- Examples of specific bands of interest include passive bands recognized for protection in the International Telecommunication Union (ITU) Radio Regulations (RR) such as 1400 – 1427 MHz, 1610.6 – 1613.8 MHz, 2690 – 2700 MHz, 10.68 – 10.7 GHz, 15.35 – 15.4 GHz, 18.6 – 18.8 GHz, 23.6 – 24 GHz, 42.5 – 43.5 GHz, 50.2 – 50.4 GHz, and other bands noted as allocated to passive services or explicitly noted in RR No. 5.340 and 5.149 [3].
- Research may also include exploring new frequency allocations, sharing and compatibility studies, measurement or characterization of the radio noise floor, or other applications within the EM spectrum. Research may facilitate dynamic sharing with active and passive users, including topics such as device control, hardware infrastructure and software systems for real-time waveform detection and spectrum sensing, leading to the establishment of a test bed in synergy with a future National Radio Dynamic Zone (NRDZ) [4, 5], which seeks to protect normal receivers outside a defined geographic region from transmitters inside the zone. Such transmitters may include experimental wireless systems utilizing new types of waveforms, new spectrum bands and/or high power levels. The long-term goal is to provide enhanced spectrum usability and access for both passive and active users of the spectrum, piloting experimental technology in a few limited, yet diverse, geographic areas, to enable wider future deployments.

Group B: Innovations on Hardware Technologies, System Architectures, Algorithms, Machine Learning and AI

High Performance RF/Analog/Mixed-Signal Hardware Technologies through Cross-Layer Design - As more and more emphasis are placed on mmWave and even THz frequency bands significant advances are needed in hardware technologies that can realize the full potential for those frequency bands. High performance hardware technologies are also in need for frequencies beyond the currently used commercial wireless applications, e.g., 6 GHz. Key challenges in the hardware innovation front may include output power, efficiency, latency, size, thermal management, hardware security, bandwidth, etc. Researchers should focus on addressing challenges from the ground up, e.g. from devices to circuits to higher layers through cross-layer design. Examples may include, but are not limited to:

- Novel high-performance semiconductor devices and innovative circuits to build components, algorithms and methodologies that either significantly improve system performance and/or allow the creation of new interference-immune systems;
- High-performance filters, antennas and radiating surfaces or apertures, amplifiers, mixers, receivers, communication theory methods and algorithms, and network protocols to ensure effective coordination among users, systems, and platforms;
- Novel higher layer protocols that can leverage improvements in devices, e.g., the improvement of medium access when new devices can provide better co-channel and/or adjacent channel interference rejection due to hardware and algorithmic improvements;
- Potentially transformative high-performance semiconductor devices, circuits, modules, protocols, algorithms, and systems that use new materials, methods or techniques and achieve significant size and weight (for hardware) reduction and cost savings (for products) to facilitate their ubiquitous deployment and usage; and
- Hardware, communication, and networking technologies for passive or semi-passive low-power systems and networks, underwater communications, and communications in extreme environments, e.g., in polar areas and space.

Secured and/or verifiable spectrum use through RF/Analog/Mixed-Signal Techniques – Security and verifiability are of paramount importance to protect storage and flow of information and ensure trust in any coexistence scheme. While the EM spectrum is being shared by an increasing number of wireless devices, it is critical to ensure the security of wireless communications and sensing. Innovative approaches to enhance communication and network security and verification are strongly encouraged.

- These approaches could include a combination of RF, analog, mixed-signal, protocol and/or algorithmic techniques;

- Proposed cross-layer solutions should include physical layer hardware and protocols. Solutions restricted to a single layer are better suited to existing core programs in the individual participating divisions named in this solicitation; and
- Innovative low-cost security techniques for unlicensed band applications (e.g., WiFi, RFID, MICS etc.)

System Architectures, Designs, and Algorithms – Future communication systems need to operate in more challenging scenarios with higher stringent performance requirements. These may include for example, higher carrier frequencies, higher spectrum utilization efficiency, low and intermittent available power, coexistence with other active and passive radio systems, lower latencies, high user density, and fast changing environments. Novel architectures, system designs, and algorithms that can significantly improve suitably defined system performances and are customized for target applications are desirable. These may include, but are not limited to:

- System design and algorithms that can better cope with channel and device uncertainties and imperfections such as carrier frequency offset and phase noises at higher carrier frequencies;
- Reconfigurable surfaces that can adaptively change the electromagnetic wave propagation environment and associated design, control and optimization algorithms;
- System designs and innovative solutions for rural wireless broadband access; and
- Distributed wireless communication and scheduling algorithms and designs for machine learning applications.

Innovations in Spectrum Use, Management, and Operations through Machine Learning and AI – Many of the innovative technologies to be developed in the future for wireless systems and networks will exploit machine learning and AI to make the biggest impacts on society. Examples may include, but are not limited to new ML and AI techniques that:

- Offer novel and efficient transmitter and/or receiver designs that compete with conventional model-based techniques;
- Facilitate spectrum sharing and access and interference-free communication;
- Enable worst-case low latency (10 ms or less) communications between thousands of user devices per base station and associated edge infrastructure;
- Enhance robustness, security, resiliency, and reliability of wireless networks offering critical services.

The current solicitation puts a special emphasis on teaming and collaboration for example between semiconductor device researchers, circuit designers, physical layer designers, and network and protocol layer researchers. Research targeting security in the physical layer and/or the network and protocol layers that address the needs for secure next generation wireless systems and networks are encouraged.

The SWIFT program will require cross-layer collaboration or teaming to succeed and make the most meaningful impact. Proposers must have complementary expertise, e.g., hardware and protocols. Proposals must have collaborative teaming to tackle cross-layer issues. Proposals that do not have cross-layer collaboration or teaming will not be considered for this solicitation; rather, they may be more appropriate for core programs in the participating divisions.

The program also encourages different research communities to work together to meet the challenges of sharing the same spectrum between two or more collocated systems which could be either active-active or active-passive.

Successful projects awarded under this program are expected to create opportunities for students to learn cross-layer wireless system design, various types of wireless applications, as well as spectrum regulations. Student training enabled by this program has the potential to address unique workforce needs in government and industry as it pertains to innovating with a keen awareness of the wireless spectrum.

Proposers should consider utilizing publicly available wireless-related resources to evaluate or demonstrate their innovations. Evaluation of new technologies through wireless testbeds and collaborations with government labs or industry are examples. These could include NSF-funded platforms such as the Colosseum and PAWR platforms (see <https://advancedwireless.org> for details), publicly available open-source simulation platforms such as ns-3 (<https://www.nsnam.org>), or other platforms.

A number of relevant reports of multiple workshops, identifying challenges of spectrum existence and transmitter/receiver technologies, convened by the WSRD IWG are available online at <https://go.usa.gov/xRV8Q>. Proposers could also consider engaging spectrum stakeholders such as from industry and government agencies.

Experiments involving transmission in certain frequency bands may require a license to operate. For questions regarding the proposed frequency usage and the license requirement, please contact the NSF Electromagnetic Spectrum Management Office (email: esm@nsf.gov) for assistance.

Please note: Each proposal budget must include funding for travel for a PI or Co-PI and up to one other project participant to attend annual two-day PI meetings in the Washington, DC, area during the award period.

[3] See https://www.ntia.doc.gov/files/ntia/publications/ntia_manual_september_2017_revision.pdf

[4] https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf20079

[5] Thomas Kidd, "National Radio Quiet and Dynamic Zones," Chips, The Department of the Navy's Information Technology Magazine, April – June 2018. <https://www.doncio.navy.mil/CHIPS/ArticleDetails.aspx?ID=10299>

III. AWARD INFORMATION

Anticipated Type of Award: Standard Grant

Estimated Number of Awards: 12 to 16

Approximately 12-16 awards are anticipated, each up to \$750,000 total and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: \$12,000,000

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

The budget for a given proposal should be commensurate with the complexity of the proposed research.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.

Who May Serve as PI:

By the submission deadline, any PI, co-PI, or other senior project personnel must hold either:

- a tenured or tenure-track position, or
- a primary, full-time, paid appointment in a research or teaching position

at a US-based campus of an IHE eligible to submit to this solicitation (see above), with exceptions granted for family or medical leave, as determined by the submitting organization. Individuals with primary appointments at for-profit non-academic organizations, non-profit non-academic organizations, or at overseas branch campuses of US IHEs are not eligible.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may be listed as PI, co-PI, and/or senior personnel on only one proposal submitted in response to this solicitation. In the event that an individual exceeds this limit, only the first proposal received before the deadline will be accepted, and the remainder will be returned without review.

Additional Eligibility Info:

Proposals must include two or more PI and Co-PI forming a team with complementary expertise. Synergistic collaborations or partnerships with industry or government are encouraged where appropriate, though no NSF funds will be provided to these organizations.

Researchers from foreign academic institutions who contribute essential expertise to the project may participate as senior personnel or collaborators but may not receive NSF support.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via FastLane, Research.gov, or Grants.gov.

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.
- Full Proposals submitted via Research.gov: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal and Award Policies and Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov. The Prepare New Proposal setup will prompt you for the program solicitation number.
- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov*. The complete text of the *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper

copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via FastLane or Research.gov. PAPPG Chapter II.D.3 provides additional information on collaborative proposals.

See PAPPG Chapter II.C.2 for guidance on the required sections of a full research proposal submitted to NSF. Please note that the proposal preparation instructions provided in this program solicitation may deviate from the PAPPG instructions.

Proposal titles should begin with "SWIFT:" then the title. If you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with "Collaborative Research:" followed by " SWIFT:", then the title. If you submit a proposal addressing the "NRDZ" then the proposal title should begin with "SWIFT:" followed by "NRDZ:" then the title.

Collaborative proposals that address the "NRDZ" should have a title that begins with "Collaborative:" followed by "SWIFT:" followed by "NRDZ:" then the title.

The Project Description must contain, as a separate section of less than a page, a section labeled "Addressing SWIFT Solicitation Specific Review Criteria". This section should provide a description of how the SWIFT solicitation specific review criteria are addressed in the proposal and include references to other relevant sections in the proposal for additional details.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

Each proposal budget must include funding for travel to Washington, DC, for a PI or Co-PI and up to one other project participant to attend annual two-day PI meetings in the Washington, DC, area during the award period.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

March 05, 2021

D. FastLane/Research.gov/Grants.gov Requirements

For Proposals Submitted Via FastLane or Research.gov:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. To prepare and submit a proposal via Research.gov, see detailed technical instructions available at: https://www.research.gov/research-portal/appmanager/base/desktop?_nfpb=true&_pageLabel=research_node_display&_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html. For FastLane or Research.gov user support, call the FastLane and Research.gov Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov or rgov@nsf.gov. The FastLane and Research.gov Help Desk answers general technical questions related to the use of the FastLane and Research.gov systems. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: <https://www.grants.gov/web/grants/applicants.html>. In addition, the NSF Grants.gov Application Guide (see link in Section V.A) provides instructions regarding the technical preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

Submitting the Proposal: Once all documents have been completed, the Authorized Organizational Representative (AOR) must submit the application to Grants.gov and verify the desired funding opportunity and agency to which the application is submitted. The AOR must then sign and submit the application to Grants.gov. The completed application will be transferred to the NSF FastLane system for further processing.

Proposers that submitted via FastLane or Research.gov may use Research.gov to verify the status of their submission to NSF. For proposers that submitted via Grants.gov, until an application has been received and validated by NSF, the Authorized Organizational Representative may check the status of an application on Grants.gov. After proposers have received an e-mail notification from NSF, Research.gov should be used to check the status of an application.

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program for acknowledgement and, if they meet NSF requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF either as *ad hoc* reviewers, panelists, or both, who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal. In addition, Program Officers may obtain comments from site visits before recommending final action on proposals. Senior NSF staff further review recommendations for awards. A flowchart that depicts the entire NSF proposal and award process (and associated timeline) is included in PAPPG Exhibit III-1.

A comprehensive description of the Foundation's merit review process is available on the NSF website at: https://www.nsf.gov/bfa/dias/policy/merit_review/.

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Building the Future: Investing in Discovery and Innovation - NSF Strategic Plan for Fiscal Years (FY) 2018 – 2022*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

NSF's mission calls for the broadening of opportunities and expanding participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines, which is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

A. Merit Review Principles and Criteria

The National Science Foundation strives to invest in a robust and diverse portfolio of projects that creates new knowledge and enables breakthroughs in understanding across all areas of science and engineering research and education. To identify which projects to support, NSF relies on a merit review process that incorporates consideration of both the technical aspects of a proposed project and its potential to contribute more broadly to advancing NSF's mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF makes every effort to conduct a fair, competitive, transparent merit review process for the selection of projects.

1. Merit Review Principles

These principles are to be given due diligence by PIs and organizations when preparing proposals and managing projects, by reviewers when reading and evaluating proposals, and by NSF program staff when determining whether or not to recommend proposals for funding and while overseeing awards. Given that NSF is the primary federal agency charged with nurturing and supporting excellence in basic research and education, the following three principles apply:

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.
- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

With respect to the third principle, even if assessment of Broader Impacts outcomes for particular projects is done at an aggregated level, PIs are expected to be accountable for carrying out the activities described in the funded project. Thus, individual projects should include clearly stated goals, specific descriptions of the activities that the PI intends to do, and a plan in place to document the outputs of those activities.

These three merit review principles provide the basis for the merit review criteria, as well as a context within which the users of the criteria can better understand their intent.

2. Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board approved merit review criteria. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. (PAPPG Chapter II.C.2.d(i). contains additional information for use by proposers in development of the Project Description section of the proposal). Reviewers are strongly encouraged to review the criteria, including PAPPG Chapter II.C.2.d(i), prior to the review of a proposal.

When evaluating NSF proposals, reviewers will be asked to consider what the proposers want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful. These issues apply both to the technical aspects of the proposal and the way in which the project may make broader contributions. To that end, reviewers will be asked to evaluate all proposals against two criteria:

- **Intellectual Merit:** The Intellectual Merit criterion encompasses the potential to advance knowledge; and
- **Broader Impacts:** The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

The following elements should be considered in the review for both criteria:

1. What is the potential for the proposed activity to

- a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
 - b. Benefit society or advance desired societal outcomes (Broader Impacts)?
2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
 3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
 4. How well qualified is the individual, team, or organization to conduct the proposed activities?
 5. Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

Proposers are reminded that reviewers will also be asked to review the Data Management Plan and the Postdoctoral Researcher Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

All proposals must clearly address the following solicitation-specific review criteria through well-identified proposal elements:

- How effectively does the proposed research address the challenges of spectrum utilization and/or coexistence?
- How likely is the proposed cross-layer research to lead to future wireless technology breakthroughs or does the potential payoff justify the risk of investing in the activity?
- Does the proposed research contain the required collaborative teaming to address research challenges across multiple layers including the physical and higher layers?

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review.

Reviewers will be asked to evaluate proposals using two National Science Board approved merit review criteria and, if applicable, additional program specific criteria. A summary rating and accompanying narrative will generally be completed and submitted by each reviewer and/or panel. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF strives to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new awardees may require additional review and processing time. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director acts upon the Program Officer's recommendation.

After programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications. After an administrative review has occurred, Grants and Agreements Officers perform the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by the NSF Grants and Agreements Officer does so at their own risk.

Once an award or declination decision has been made, Principal Investigators are provided feedback about their proposals. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers or any reviewer-identifying information, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See Section VI.B. for additional information on the review process.)

B. Award Conditions

An NSF award consists of: (1) the award notice, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award notice; (4) the applicable award conditions, such as Grant General Conditions (GC-1)*; or Research Terms and Conditions* and (5) any announcement or other NSF issuance that may be incorporated by reference in the award notice. Cooperative agreements also are administered in accordance with NSF Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC) and the applicable Programmatic Terms and Conditions. NSF awards are electronically signed by an NSF Grants and Agreements Officer and transmitted

electronically to the organization via e-mail.

*These documents may be accessed electronically on NSF's Website at https://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer no later than 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). No later than 120 days following expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

Failure to provide the required annual or final project reports, or the project outcomes report, will delay NSF review and processing of any future funding increments as well as any pending proposals for all identified PIs and co-PIs on a given award. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through Research.gov, for preparation and submission of annual and final project reports. Such reports provide information on accomplishments, project participants (individual and organizational), publications, and other specific products and impacts of the project. Submission of the report via Research.gov constitutes certification by the PI that the contents of the report are accurate and complete. The project outcomes report also must be prepared and submitted using Research.gov. This report serves as a brief summary, prepared specifically for the public, of the nature and outcomes of the project. This report will be posted on the NSF website exactly as it is submitted by the PI.

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

VIII. AGENCY CONTACTS

Please note that the program contact information is current at the time of publishing. See program website for any updates to the points of contact.

General inquiries regarding this program should be made to:

- Mohammod Ali, telephone: (703) 292-4632, email: moali@nsf.gov
- Alexander Sprintson, telephone: (703) 292-8950, email: asprints@nsf.gov
- Zhengdao Wang, telephone: (703) 292-7823, email: zwang@nsf.gov
- Lawrence S. Goldberg, telephone: (703) 292-8339, email: lgoldber@nsf.gov
- Albert Z. Wang, telephone: (703) 292-7230, email: awang@nsf.gov
- Jonathan V. Williams, telephone: (703) 292-2455, email: jonwilli@nsf.gov
- Murat Torlak, telephone: (703) 292-7748, email: mtorlak@nsf.gov
- Bevin A. Zauderer, telephone: (703) 292-2428, email: bezauder@nsf.gov
- Lisa M. Winter, telephone: (703) 292-8519, email: lwinter@nsf.gov

For questions related to the use of FastLane or Research.gov, contact:

- FastLane and Research.gov Help Desk: 1-800-673-6188
- FastLane Help Desk e-mail: fastlane@nsf.gov
- Research.gov Help Desk e-mail: rgov@nsf.gov

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding

opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF [Grants Conferences](#). Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on [NSF's website](#).

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at <https://www.grants.gov>.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 55,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Arctic and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities (FASSED) provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See the *NSF Proposal & Award Policies & Procedures Guide* Chapter II.E.6 for instructions regarding preparation of these types of proposals.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment or general information. TDD may be accessed at (703) 292-5090 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at <https://www.nsf.gov>

- **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
- **For General Information** (NSF Information Center): (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**
 - Send an e-mail to: nsfpubs@nsf.gov
 - or telephone: (703) 292-8134
- **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; and project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See [System of Record Notices](#), NSF-50, "Principal Investigator/Proposal File and Associated Records," and NSF-51, "Reviewer/Proposal File and Associated Records." Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

An agency may not conduct or sponsor, and a person is not required to respond to, an information collection unless it displays a valid Office of Management and Budget (OMB) control number. The OMB control number for this collection is 3145-0058. Public reporting burden for this collection of information is estimated to average 120 hours per response, including the time for reviewing instructions. Send comments regarding the burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to:

Suzanne H. Plimpton
Reports Clearance Officer
Office of the General Counsel
National Science Foundation
Alexandria, VA 22314

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Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (703) 292-5090 or (800) 281-8749

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