DAY ONE PROJECT

A Convergence Directorate at the National Science Foundation

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Summary

Convergence is a compelling novel paradigm and a potent force for advancing scientific discovery via transdisciplinary collaboration. It is also a useful framework for multi-sector partnerships. The next administration should form a Convergence Directorate at the National Science Foundation (NSF) to accelerate research and innovation and help ensure U.S. leadership in the industries of the future.

In forming the Directorate, NSF should:

- Commit resources that are commensurate with the importance of the Directorate's mission.
- Provide the sustained focus needed to realize the tremendous potential of convergence.
- Ensure that the Directorate is organized to reflect the principles of convergence in its structure and operations.

Challenge and Opportunity

We are approaching a period in which scientific discovery will be driven by an integration of distinct disciplines and sectors. Convergence involves connecting the deep expertise of the disciplinary sciences across intellectual and organizational boundaries. It refers to research which has two primary characteristics[1]:

- **Deep integration across disciplines.** As experts from different disciplines pursue common research challenges, their knowledge, theories, methods, data, research communities, languages, and modes of thinking become increasingly intermingled or integrated.
- **Research driven by a specific and compelling problem.** Convergence research is generally inspired by the need to address a specific challenge or opportunity, whether it arises from deep scientific questions or pressing societal needs.

The assertion that convergence should have a central role in the U.S. strategy for research and development is grounded in the findings of reports from stakeholders such as the American Academy of Arts and Sciences[2], the Massachusetts Institute of Technology[3], the National

[1] National Science Foundation. 2017. Convergence Research at NSF. https://www.nsf.gov/od/oia/convergence/index.jsp.
[2] American Academy of Arts and Sciences. 2013. ARISE 2: Unleashing America's Research & Innovation Enterprise. https://www.amacad.org/sites/default/files/publication/downloads/arise2.pdf.
[3] Massachusetts Institute of Technology. Washington Office. 2011. The Third Revolution: The Convergence of the Life Sciences, Physical Sciences, and Engineering; Massachusetts Institute of Technology. 2016. Convergence: The Future of Health. Massachusetts Institute of Technology, Cambridge, Massachusetts.

Academy of Sciences[4], and the President's Council of Advisors on Science and Technology[5]. The formation of a Convergence Directorate also aligns with recent legislative efforts such as the Endless Frontiers Act.[6]

In the report *ARISE 2: Unleashing America's Research & Innovation Enterprise*[2], the American Academy of Arts and Sciences delineates two goals for the U.S. science and technology enterprise:

1) Promote a deep conceptual and functional integration across scientific disciplines.
2) Foster cooperative, synergistic interactions among academia, government, and the private sector throughout the discovery and development process.

The National Academy of Sciences[5] similarly affirms the importance of convergence in advancing scientific discovery and in stimulating innovation and future economic development. Their report on convergence notes the "need for a broad understanding of best practices on the effective transfer of technology from research organizations into the private sector."

In the report *The Perils of Complacency: America at a Tipping Point in Science and Engineering*[7], the American Academy of Arts and Sciences warns that the U.S.'s ability to respond to other countries' rise in science and engineering, particularly that of China, is likely to be impeded by increasingly severe fiscal constraints on nonmilitary discretionary spending. The report highlights the critical need for "an integrated, coherent federal funding strategy" and observes "the countries that succeed will be those that not only make the greatest discoveries but innovate the fastest." Initiatives such as the NSF Convergence Accelerator[8] are a critical component of the U.S. strategy to accelerate use-inspired convergence research via public-private partnerships in areas of national importance.

Responding to this imperative, many countries are giving convergence and transdisciplinary research a prominent role in their national R&D strategy. The National Science Foundation of China (NSFC) states: "transdisciplinary and convergent research are playing a leading role in the development of science and technology, while the national demands for meeting global

[4] National Research Council of the National Academy of Sciences. 2014. Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. Washington, DC and NRC. 2019. Fostering the Culture of Convergence in Research: Proceedings of a Workshop, Washington, DC.
[5] PCAST. 2020. Recommendations for Strengthening American Leadership in Industries of the Future. https://science.osti.gov/-/media/_/pdf/about/pcast/202006/PCAST_June_2020_Report.pdf?la=en&hash=019A4F17C79FDEE5005C51D3D6CAC81FB31E3ABC.
[6] The United States Senate Bill S.3832. 2020. The Endless Frontiers Act. https://www.congress.gov/116/bills/s3832/BILLS-116s3832is.pdf.
[7] American Academy of Arts and Sciences. 2020. THE PERILS OF COMPLACENCY: America at a Tipping Point in Science and Engineering. https://www.amacad.org/sites/default/files/publication/resources/Perils-of-Complacency_Full-Report.pdf.
[8] National Science Foundation. NSF Convergence Accelerator | NSF □ National Science Foundation. https://www.nsf.gov/od/oia/convergence-accelerator/.

challenges and advancing original innovation are more pressing than ever before."[9] A series of press releases from Zhejiang University announcing the funding of ten convergence research projects in the past two years (as part of its Innovation 2030 plan) illustrates the important role of convergence in China's strategic planning for R&D.[10]

A sustained focus on convergence represents a culture shift for NSF as well as academic institutions because they are organized primarily to advance disciplinary research. The National Research Council has highlighted the significant challenges inherent in creating the administrative, research, teaching, partnership, and funding structures necessary to promote convergence research.[11]

The report of the National Academies' workshop on *Fostering the Culture of Convergence in Research*,[12] points out that peer review is typically a conservative process oriented towards safe bets. The report states the need to identify review criteria to evaluate the potential of highly convergent (and perhaps risky) projects. "Peer reviewers having deep expertise in a certain area may not have sufficient expertise across the multiple areas involved in a convergent proposal to fully evaluate its merit." The National Science Foundation of China (NSFC) similarly affirms this need for new review processes to evaluate convergence proposals, and they have announced their intention to address it.[9]

Currently, NSF has a diffused set of programs and initiatives that seek to address these goals, but they lack focus and coordination, and the total investment in these programs is far too small to accomplish the objectives.

Plan of Action

The next administration, building on the recommendations of a broad range of stakeholders, should establish a Convergence Directorate at the National Science Foundation. This Directorate

[9] National Natural Science Foundation of China. NSFC at a Glance. 2020. http://www.nsfc.gov.cn/english/site_1/about/6.html
[10] Zhejiang University. Intelligence Convergence Project http://www.cmm.zju.edu.cn/cmmenglish/2020/0721/c52682a2172322/page.htm; , Asian Civilizations Project, https://www.zju.edu.cn/english/2020/0629/c19573a2158813/page.htm; Another four convergence research projects. https://www.zju.edu.cn/english/2020/0409/c19573a2044470/page.htm.
[11] National Research Council of The National Academies of Sciences, Engineering and Medicine. 2014. Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. Washington, DC. https://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering.
[12] The National Academies of Sciences, Engineering and Medicine. 2019. Fostering the Culture of Convergence in Research: Proceedings of a Workshop. https://www.nap.edu/catalog/25271/fostering-the-culture-of-convergence-in-research-proceedings-of-a.

should be charged with promoting convergence research and education, and with accelerating the translation from research to practice in areas of national importance.

The structure of a Convergence Directorate must reflect its mission. The Directorate should be more than a re-organization of existing NSF programs and activities. It must address the challenges and barriers—both internal and external to NSF—that must be overcome if the great promise of convergence is to be realized.[5] Its internal operations and staffing should reflect deep integration of diversity, it should advance innovate processes for transdisciplinary review of projects, and it should have clear strategic focus on accelerating the most important discoveries and innovation.

The internal operations of the Directorate should reflect the principles of convergence, displaying a deep integration of diverse perspectives and approaches. The Directorate leadership and staff should be selected for their ability to advance Convergence, rather than for solely disciplinary achievements. Furthermore, they should be recruited from multiple sectors, including academia, government, and the private sector.

The Directorate should establish a review process capable of identifying and selecting the most promising Convergence projects. As emphasized by the National Academies report, convening a diverse panel of disciplinary experts is not sufficient for this purpose.[13] Rather, the Convergence Directorate must advance state of the art transdisciplinary review and evaluation.

Finally, the Convergence Directorate must have a strong strategic focus to enable NSF to greatly accelerate discovery and innovation in areas of national importance. The Directorate will be capable of a central role in ensuring American leadership in the industries of the future: advanced manufacturing, artificial intelligence, biotechnology, advanced communications and cybersecurity, and quantum information science.[7]

NSF took a bold step in naming convergence as one of its Ten Big Ideas for Future NSF Investments and in subsequently developing new programs to promote convergence research and education across the Foundation.[14] To fully realize the promise of these initial efforts, the next administration should create a Convergence Directorate at the National Science Foundation.

[13] The National Academies of Sciences, Engineering and Medicine. 2019. Fostering the Culture of Convergence in Research: Proceedings of a Workshop. https://www.nap.edu/catalog/25271/fostering-the-culture-of-convergence-in-research-proceedings-of-a.

[14] National Science Foundation. 2016. 10 Big Ideas for Future NSF Investments.

Frequently Asked Questions

Why is a new Directorate needed to advance Convergence research at NSF?

The NSF Directorates have evolved primarily along disciplinary lines over the past 70 years and have maintained their emphasis on curiosity-driven research in accordance with NSF's unique role in supporting fundamental research. Their traditional mission remains important, and the NSF Directorates are structured appropriately to meet it. These Directorates, however are not ideally positioned to advance a deep integration of disciplines and promote use-inspired research.

A new Directorate will enable NSF to better address the distinct challenges and opportunities of convergence. It will complement, not supplant, existing strengths and resources at NSF. Universities have recognized the need for new mechanisms and infrastructure to catalyze convergence research, and have responded by creating new departments, launching centers and institutes, and reforming faculty hiring and promotion. NSF must similarly evolve if it is to successfully support convergence.[15]

Would the formation of a Convergence Directorate enhance NSF's ability to foster cross-sector partnerships?

Yes. Currently much of the NSF expertise on technology transfer and private sector partnerships is located within the Engineering Directorate in the Division of Industrial Innovation and Partnerships (IIP). Programs currently housed in IIP, such as Innovation Corps (I-Corps), the Industry-University Cooperative Research Centers Program (IUCRC), the Small Business Innovation Research Program (SBIR), and the Small Business Technology Transfer Program (STTR), are aligned with the cross-cutting mission of the Convergence Directorate. These programs would have greater impact within the Convergence Directorate, with more funding and a scope that embraces the full spectrum of science and engineering supported by NSF. In a similar manner, programs such as Growing Convergence Research and the Convergence Accelerators, currently housed within the Office of Integrative Activities, can better realize their potential within the Convergence Directorate.

Should workforce development and broadening participation be part of the mission of the Convergence Directorate?

[15] National Research Council of the National Academies of Sciences, Engineering, and Medicine. 2014. Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. https://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering.

Yes. The Convergence Directorate should promote convergence education, workforce development, and broadening participation in partnership with the other NSF Directorates. These are essential to the success of the Convergence Directorate, and to the Foundation as a whole. The National Research Council emphasizes the importance of revising STEM education to facilitate convergence in its 2014 report *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond.*[16] A 2019 workshop, *Global Perspectives in Convergence Education*, sponsored by the National Science Foundation (NSF), the Organization for Economic Cooperation and Development (OECD), the U.S. National Academy of Sciences, Engineering and Medicine (NASEM), and the University of Southern California (USC), addressed the outlook and requirements for convergence education from K-12 through adult education.[17]

How is convergence related to recent legislative efforts such as the *Endless Frontier Act*?

The Endless Frontier Act[18] would re-designate the National Science Foundation as the National Science and Technology Foundation and establish a new Directorate for Technology. The goals of the new Directorate are to strengthen the leadership of the United States in critical technologies through fundamental research and education in key technology focus areas and to foster an accelerated translation of fundamental advances in those areas. These are the goals that a Convergence Directorate is designed to address. The Endless Frontier Act recognizes that "without a significant increase in investment in research, education, technology transfer, and the core strengths of the United States innovation ecosystem, it is only a matter of time before the global competitors of the United States overtake the United States in terms of technological primacy."

[16] National Research Council of the National Academies of Sciences, Engineering, and Medicine. 2014. Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. https://www.nap.edu/catalog/18722/convergence-facilitating-transdisciplinary-integration-of-life-sciences-physical-sciences-engineering.

[17] Herr et al. 2019. Convergence education-an international perspective. J Nanopart Res 21:229. https://doi.org/10.1007/s11051-019-4638-7.

[18] The United States Senate Bill S.3832. 2020. The Endless Frontiers Act. The United States Senate Bill S.3832. 2020. The Endless Frontiers Act. https://www.congress.gov/116/bills/s3832/BILLS-116s3832is.pdf.

About the Authors

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