Fall 2024

ENGINEERING A DIVERSE FUTURE

The BRIDGE

LINKING ENGINEERING AND SOCIETY

NATIONAL ACADEMY OF ENGINEERING

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Mission Statement of *The Bridge*

The Bridge publishes articles on engineering research, education, and practice; science and technology policy; and the interface between engineering and technology and society. The intent is to stimulate debate and dialogue both among members of the National Academy of Engineering (NAE) and in the broader community of policymakers, educators, business leaders, and other interested individuals. *The Bridge* relies on its editor in chief, NAE members, and staff to identify potential issue topics and guest editors. Invited guest editors, who have expertise in a given issue's theme, are asked to select authors and topics, and independent experts are enlisted to assess articles for publication. The quarterly has a distribution of about 7000, including NAE members, members of Congress, agency officials, engineering deans, department heads, and faculty, and interested individuals all over the country and the world. Issues are freely accessible at *www.nae.edu/TheBridge*.

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The BRIDGE

LINKING ENGINEERING AND SOCIETY

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News and Notes

A Word from the NAE Chair

Increasing the National Academy of Engineering's Impact on Society

Erroll B. Davis Jr. (NAE), chair, the National Academy of Engineering

Having assumed the role of chair of the National Academy of Engineering (NAE) Council on July 1 of this year, this is, of course, my first opportunity to address the engineering community from this position. Let me start by saying that it was a great honor to be elected but it is also a great challenge to follow in the footsteps of my predecessor, Don Winter. Like him, I am hopeful that I can give back both to the engineering community and to the nation.

As has been the normal practice, the NAE's president, John Anderson, and I will alternate authorship of this quarterly column in *The Bridge*. As I begin to enumerate my challenges, one, unfortunately, will be helping to find a replacement for John, who is scheduled to retire during my two-year term.

There is an old adage that says that you come into the world with nothing, and you will leave with nothing. The only thing you can do while here is to have an impact. When you think about this, it immediately becomes clear that those of us who have been rigorously trained to be problem-solvers have the ability to have a great impact on society. My belief is that if we have been blessed with this capability, then we also have a moral obligation to share our capabilities and expertise. This is what engineers have done by solving many of the world's problems in a systematic and logical manner. How, where, and when we have an impact are questions the NAE's membership must deal with on an ongoing basis.

My view is that for the NAE to have a greater impact on society, it must do two things simultaneously. First, based on the projected need for talented US engineers in the future, the NAE must work to increase the sheer number of engineers. Historically, the United States has been blessed with access to a high percentage of immigrant engineers. However, this does not change the fact that we absolutely must do a better job of developing and accessing the talent of all US citizens.

Secondly, we must amplify the role that the NAE and the National Research Council play with the policymakers of this nation.

Producing more highly qualified engineers is a daunting task. Assuming that we can do so by depending upon elite institutions filled with students from elite high schools is, from my estimation, not the best plan. At one point in my career, I had the opportunity to serve as the superintendent of a large urban school system. It was both the hardest and most rewarding job of my career. The challenges were numerous and well known, from funding to teacher quality to the absence of technology to the unequitable distribution of resources, and on and on. The predominant impression that this experience had upon me was that we are wasting and not developing enough talent in our public schools. The problems are there, and engineers must be a part of the solution if we are to develop more effective pathways for students interested in becoming engineers. The potential for impact is massive here, not only on the engineering profession but on society in general, as it welcomes more real problem-solvers into its ranks. Despite its obvious complexity and the sheer number of daunting obstacles, the pathway problem must be solved, and the NAE must play a critical role in that process.

Simultaneously, we can work to increase the ongoing impact of the NAE on this nation. In a world of sometimes alternate facts, we can have an impact today by primarily giving sound, objective, and nonpartisan advice when asked. Government agencies and governing bodies have historically sought out and depended upon advice from the National Academies. In many ways, however, this is a reactive role. We must ask ourselves whether this is the best way to maximize the impact of the NAE. As engineers, we are very used to letting the facts speak for themselves. But in a world of alternate facts, we may need to speak a bit more loudly and a bit more frequently. We need to ask if our current processes are the best in today's world. Do they take too long? Are we spirited advocates of our positions, or are we just putting the well-researched facts out there?

Another harsh reality, however, is that serious funding challenges exist, even with the current process, in which our major expenses are not compensation for the pro bono researchers and study participants but merely the funding of their expenses, which continue to increase over time.

In short, we must first face the challenges of funding the current model. Secondly, I believe we must challenge ourselves to ask: In an AI world crying out for guidance and responsible direction, is a reactive approach still the answer? And, if we conclude that it isn't, how can we proactively increase our impact while maintaining both our objectivity and our financial solvency?

If we are to have a greater impact, we must increase the number of engineering voices heard over time, both by increasing the number of engineers and by giving more advice in an objective and nonpartisan manner to the policymakers of this nation.

In today's world, standing still or doing the things we have always done will not enable us to remain relevant and is an ineffective formula for increasing our impact.

I look forward to discussing these issues and many others further with all members of the NAE.

The President's View

The Power of Diversity, Equity, and Inclusion in Engineering

John L. Anderson (NAE), president, the National Academy of Engineering

As a graduate student in 1968 at the University of Illinois, I volunteered to tutor minority undergraduate students who were enrolled in Project 500,[1] a pilot project to increase the diversity of the undergraduate student body. I was assigned five undergraduate students who were in their first year of science and engineering study. All five dropped out after one semester; they lacked the foundational knowledge in mathematics and the sciences needed to succeed in an engineering or science curriculum. It was later recognized that the planning for Project 500 lacked diverse input. It lacked the inclusion of diverse ideas, some of which might have slowed the process but would have increased the chances of success for these minority students. This example highlights the important relationship between diversity *and inclusion* in decision-making processes.

The mission of the National Academy of Engineering is to advise the nation about matters of engineering and technology, and to advance the engineering profession. The US Census Bureau predicts that White males will comprise only 22% of the US population by the year 2060, and a smaller percentage of the college-age population.[2] We must attract and educate engineers from the remaining 80% of our citizens if we are to fulfill this mission.[3] To quote John Brooks Slaughter, "We must let opportunity meet talent."[4]

There is no easy fix to improving diversity within STEM fields. It is a systems problem, with the various elements depending on each other and with history and socioeconomics compounding the challenges. But we must move forward toward our goals for diversity and, very importantly, use diversity to improve our organizations. In any profession, the inclusion of minority populations in governance and decision-making will always be challenging because of the dynamics of human networking. As noted in a Rand analysis of promotions of flag officers in the military, "Ducks pick ducks."[5] We must resist this instinctive behavior.

This issue of *The Bridge* addresses DEI in the engineering profession and articulates why progress in all three areas is critical for the advancement of engineering and technology in the United States. The authors of the articles have made significant contributions to engineering

[1] guides.library.illinois.edu/c.php?g=348250&p=2350891

[2] www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf

[3] www.nae.edu/305234/Presidents-Perspective-The-Diversification-of-the-National-Academy-of-Engineering

[4] www.nationalacademies.org/news/2020/10/we-must-let-opportunity-meet-talent

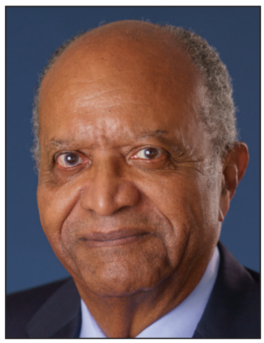
[5] news.usni.org/2020/08/12/report-to-pentagon-on-culture-of-flag-general-officers-across-services

and human resources as educators, practitioners, and researchers; they speak from experience as leaders in academia, business, and government. Throughout my career I have seen many positive changes in the composition of and leadership in the engineering workforce, due in great measure to attention paid to diversity, equity, and inclusion. I am certain such progress will continue. We must be successful in this endeavor to maintain our strong position in technology and innovation. I am confident we will.

Guest Editors' Note

An Inclusive and Diverse Engineering Profession: Why It Is Important and How to Achieve It

Wanda A. Sigur



Percy A. Pierre

Wanda A. Sigur (NAE) is retired vice president and general manager, civil space, Lockheed Martin Corporation. Percy A. Pierre (NAE) is Glenn L. Martin Endowed Adjunct Professor, the University of Maryland, College Park. He is the founding chairman of the NAE's Racial Justice and Equity Committee.

There are decisive moments in our nation's history that drive change. Fifty years ago, the Nixon administration's new affirmative action policy, called the Philadelphia Plan, built upon the policies of earlier administrations and required companies to meet certain hiring goals for minorities with a penalty of canceled government contracts for noncompliance. While the Philadelphia Plan did not focus on engineering jobs, engineering companies with significant federal engineering contracts saw the implications for their engineering workforce. For companies hiring engineers, industry responded by noting that there were too few minority graduates to meet any reasonable goal. Instead, they offered to work to increase the number of minority engineers, with a focus on African American engineering graduates, by promising to do more of the things they were already doing to support engineering education at universities. Realizing that that process was insufficient, a small group of key leaders across industry, non-profits, and universities developed a systematic and strategic approach. With the support of the Alfred P. Sloan Foundation, they helped create many minority engineering programs that still exist. The initial success was dramatic.

In this issue of *The Bridge*, Percy Pierre (acting US secretary of the Army [former]; Glenn L. Martin Endowed Professor, University of Maryland College Park) and Catherine Weinberger (research associate, Institute for Social, Behavioral, and Economic Research, UCSB) share the 50-year history of programs to encourage, welcome, and incentivize minority engineers by acknowledging and addressing the systems engineering aspect of the national state of engineering.

This issue of *The Bridge* not only captures that history but acknowledges that times have changed. Affirmative action is gone. The Supreme Court has put up barriers to race-conscious programs, and states have cut funding for diversity programs. What has not changed are the challenges of addressing inclusion in our nation. And yet, the problem persists in new dimensions. The nation is highly dependent on immigrant engineers. About 24% of US engineers are immigrants. The significant growth of the Hispanic population over the next 25 years, the continued growth of the African American population, and the continued under-engagement of the US female population will only worsen the problem at current utilization levels of these populations. While we are fortunate to benefit from the immigration of many engineers, the need for foreign-born engineers will continue to grow if we cannot support our own populations. In his article, Norman Augustine (acting US secretary of the Army [former]; chairman and CEO, Lockheed Martin [ret.]) discusses the challenges and introduces solutions that allow us to supplement America's overall engineering capabilities by using the talents of its entire population.

The inclusion of diverse voices has contributed to discoveries that would not have been possible otherwise. For example, the omnipresent transistors we use in electronics were only possible by including the ideas of engineers, physicists, materials scientists, and even a young Egyptian American and Korean American engineering team that provided solutions to address manufacturability. As we look forward to meeting future engineering challenges, this issue of *The Bridge* discusses the people of engineering, an undeniable element of our success. We rely on knowledge, creativity, commitment, and sheer workforce numbers as key resources to address our future problems. A systems analysis approach to ensuring the availability of each of these resources is proper. And while diversity of thought and talent are critical to driving creativity, we find ourselves at a point in time when even using words like "diversity" and "inclusion" is seen as politically charged.

This issue of *The Bridge* addresses the issues around sustaining a US engineering workforce that builds on and integrates the talents and ideas of our diverse nation. A critical part of the pathways to engineering starts in K–12 education and continues into the workforce. What is needed is a systemic and strategic effort to make a difference and not just more of the same. This edition covers many aspects of inclusion and equity in engineering. As a roadmap to this issue we have asked the contributing authors to comment on various aspects of inclusion. We capture those topics as questions shown below:

Why does inclusion matter?

Norm Augustine reminds us why engineering is important, particularly in support of our national goals. Using data analytics that reflect opportunities for talent gains in view of the nation's self-imposed limits on attracting talent, Augustine points to contrasts between the US and China, where an aggressive approach to technological dominance is playing out. He offers solutions that include reassessing America's pre-K–12 education programs and priorities, providing adequate funding for necessary programs, and avoiding counterproductive laws and policies.

Does inclusion play a role in innovation?

Nicholas Donofrio (IBM Fellow Emeritus & EVP I&T [ret.]; CEO, NMD Consulting, LLC) challenges leaders to resolve the challenges of innovation by seeking inspiration from a new perspective and engaging those that might open the leader to new ideas. Through firsthand experiences, he shares how the diversity of the people included in an innovation enterprise made a difference. Using the theme of starting with a clear understanding of a problem rather than the answer, he gives multiple examples of when problem-solving was only possible when a nontraditional voice or perspective was included in an open, collaborative culture.

How have we historically addressed the challenges of increasing representation in engineering?

Underrepresented participation in engineering was addressed with participation by the NAE over 50 years ago. Percy Pierre and Catherine Weinberger share the national strategy that involved multiple corporations and universities, the government, the Sloan Foundation, and the NAE. They produced a solution that provided funding, incentivized action, and created a long-term resolution.

What is the long-cycle performance of minority engineering "pipeline" programs?

Catherine Weinberger shares her continued research on the minority engineering effort. It is undeniable that there has been an increase in the representation of women, African American, and Hispanic graduates within the college-educated workforce. However, in her long-cycle data assessment, Weinberger shows that although the success trajectory for the programs developed in the '70s resulted in significantly increased ranks of African American students in accredited engineering bachelor's degree programs, that trajectory peaked in 2000 and there was a downward shift after the first 30 years. Weinberger discusses strategies to reverse the downward trend.

Is there a continued imperative to expand access to engineering?

Kesha Moore (manager of research, NAACP Legal Defense & Educational Fund, Thurgood Marshall Institute) and Amalea Smirniotopoulos (senior policy counsel and co-manager of the Equal Protection Initiative, Legal Defense & Educational Fund) discuss the roles that policy and law have historically played in encouraging opportunity for gifted Black, Latinx, and Indigenous people in STEM fields, including the roles that "pipeline" programs have had in increasing representation. They emphasize a key point: Programs that encourage representation remain lawful and have been critical to removing barriers. They share data on unequal opportunities, highlighted by racial and ethnic disparities in access to key entry programs for engineering and other STEM careers. Highlighting the importance of inclusion, they amplify many programs and resources that are not only legal, open to all, and carefully constructed, but also critical in ensuring increasing participation in STEM fields.

Are there opportunities to address engagement and inclusion within our existing communities?

Building on the evidence-based recommendations of the NASEM consensus study *Advancing Antiracism, Diversity, Equity, and Inclusion in STEMM Organizations: Beyond Broadening Participation* (National Academies of Sciences, Engineering, and Medicine 2023), co-chairs Gilda Barabino (president and professor of biomedical and chemical engineering, Olin College of Engineering) and Susan Fiske (Emerita Eugene Higgins Professor, Department of Psychology, and School of Public and International Affairs, Princeton) provide a unique and accessible approach, sharing their perspectives on and promising practices in the next step in inclusion—going beyond tracking the numbers. Barabino and Fiske present a candid conversation that tackles uncomfortable words used to describe the environment, tough metrics that can quantify "welcoming" or the feelings of team members, systemic racism, lived experience, and personal perspectives on the wide-ranging recommendations of the study. Together, they share an optimistic view of the change that is possible.

How can we ensure performance while supporting inclusion, career development, and our teams? What about those who are already in the workforce?

Audrey Murrell (professor of business administration, psychology, and public and international affairs, the Katz Graduate School of Business, University of Pittsburgh) and Samuel Allen (the Katz Graduate School of Business, University of Pittsburgh) discuss retention and growth with a focus on mentoring and allyship supporting women in STEM. Although representation of women has increased significantly, they are still underrepresented in senior-level positions. They emphasize the imperative of alignment of organizational goals and performance or outcomes of an organization with those of the culture, including the organization's inclusion, equity, and diversity efforts to drive sustainable solutions. With a focus on retention and development, Murrell and Allen point to a number of successful practices, but place emphasis on welcoming, developing, and modeling.

Is there a vision for the future?

Building on their work done during the Obama administration in support of growth and seeding opportunity in underrepresented communities in STEM fields, Megan Smith (CEO and founder, shift7, US chief technology officer [former]; Google executive [former]) and Puneet Ahira (Amazon and Google speculative technologies lead [former]; CEO and founder, Omission Studio; independent consultant) share historic lessons learned, and flag new opportunities for driving engagement, building inclusion, and supporting future STEM needs. Joined by Wanda Sigur (VPGM, Lockheed Martin SPACE [ret.]), they also highlight that challenges of inclusion may be perceived as a systems problem using lessons from community organizing models. Using networking, communities of practice, and data analytics, successful programs—from code camps to fab labs to storytelling—are shared as the means to elevate and scale existing successful efforts.

Summary

As we look forward to future opportunities driven by tomorrow's challenges that will face America and the world, the issues of inclusion and equity continue to demand our attention and focus. As captured by Smith, Ahira, and Sigur in "Endless Talent Is the American Dream," "*To unleash the full creative and productive energies of the 342 million people alive in America today would be the greatest undertaking this country (or any) has ever made. Perhaps more than any other concerted effort, it has the power to vastly transform industry, commerce, trade, science, technology, the arts, politics, culture, health, and education in one fell swoop…Endless talent exists.*" Let's continue the journey.

There are significant opportunities to supplement America's overall engineering capabilities while leveraging the talents of its entire population.

The Uncapped Potential:

Engineering an Opportunity of a Lifetime

Norman R. Augustine (NAE, NAS) is retired chairman and CEO, Lockheed Martin Corporation.

Norman R. Augustine

Engineering is ultimately governed by the fundamental laws of nature, and nature is an absolutely fair but absolutely unforgiving judge.[1] If an engineer inadvertently leaves a "dash" out of thousands of lines of code on Mariner 1, the spacecraft that was intended to visit Venus is last observed heading into outer space to do some exploration on its own. If a seal on a rocket engine is flown outside its temperature envelope, the space shuttle Challenger fails. And if a fragment of ultralight insulation foam strikes the leading edge of the wing of the space shuttle Challenger, it too fails.

It doesn't matter how many high-level experts were involved in the design process, how much money was invested in the project, how many million people were hoping for success, or whether the designers were White, Black, Hispanic, Asian, men, or women. If the design is sound, there can be great success; if it is flawed, there can be abject failure. This applies whether building spacecraft, aircraft, bridges, tunnels, automobiles, ships, skyscrapers, or cell phones. That is one of the many attractions of engineering: Ultimately, everyone's work is judged alike.

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[1] Major sources of data for this article include the National Center for Science and Engineering Statistics of the National Science Foundation, the American Society for Engineering Education, the National Center for Education Statistics, the US Bureau of Labor Statistics, and the US Census Bureau.

But there are self-imposed problems limiting engineering in America, one of which is the constraint the nation, usually short of engineers, places on itself by failing to attract to the field more talent from the rich variety of backgrounds in its populace. Overcoming this improvidence could enable the engineering profession to make even greater contributions to the nation while offering the opportunity of a lifetime to many more of its citizens. Such contributions range from enhancing the economic wellbeing of the citizenry to improving healthcare to providing national security to preserving the viability of our planet.

Engineering Matters

The president of the People's Republic of China, Xi Jinping, himself a chemical engineer, has said that "technological innovation has become the main battleground of the global playing field and competition for technological dominance will grow increasingly fierce." His government's growing investment in science and technology suggests that he means what he says.

In the United States, a number of studies, two of which formed the basis for Nobel Prizes,[2] concluded that up to 85% of the growth in America's Gross Domestic Product (GDP) is attributable to advancements in just two closely related fields: science and technology. It is, of course, the nation's GDP that underpins its ability to provide national security, healthcare, education, infrastructure, and a higher quality of life for its citizens.

It is science and engineering that, in the past few decades alone, have provided benefits to humanity that range from artificial joints, electric vehicles, and cell phones to MRI machines, GPS, email, and high-definition television. And the future is filled with promising new technologies that include automation, artificial intelligence, genomics, massive computing, quantum communication, advanced medical imaging, and fusion-generated electricity—plus advancements that no one has yet even imagined.

To turn such enormous potential into reality will require highly trained engineers in greater quantities than are available today. Among the first to recognize—and *act* upon—this was China (see figure 1).

Given the size of China's population relative to that of the United States—China being a factor of four larger—there is no way that America can hope to compete with China on a person-for-person basis. Rather, it must do so by seeking technological advantage, a more motivated populace, alliances with its allies, and fully benefitting from the talents of individuals in all segments of its society.

Unfortunately, along with the many scientific and technological opportunities that have presented themselves to the nation, so too have many challenges. A partial list of the latter might include providing sustainable clean energy, developing large-scale affordable desalination, offering greater opportunity to all our nation's youth, providing affordable healthcare, creating quality jobs, and providing national security with armed forces that are likely to be vastly outnumbered.

But there are self-imposed problems limiting engineering in America, one of which is the constraint the nation, usually short of engineers, places on itself by failing to attract to the field more talent from the rich variety of backgrounds in its populace.

In many of these instances it will be engineers who will be called upon to provide answers to the challenges confronted. According to the Bureau of Labor Statistics, the net demand for engineers will increase by 5.2% over the next 10 years, with some fields of engineering needing to grow by 14%. In addition, 20% of the current engineering workforce will be eligible to retire within the next decade (at age 65) and will need to be replaced.

What Became of All the Engineers?

Various terms are commonly used to refer to America's scientific/technical workforce. "STEM" (science, technology, engineering, and mathematics) is perhaps most common, but is sufficiently general as to encompass 24% of the nation's overall workforce, including social scientists, technicians, psychologists, and others. In 2021, there

[2] See www.nobelprize.org/prizes/economic-sciences/1987/summary/ and www.nobelprize.org/prizes/economic-sciences/2018/romer/facts/.

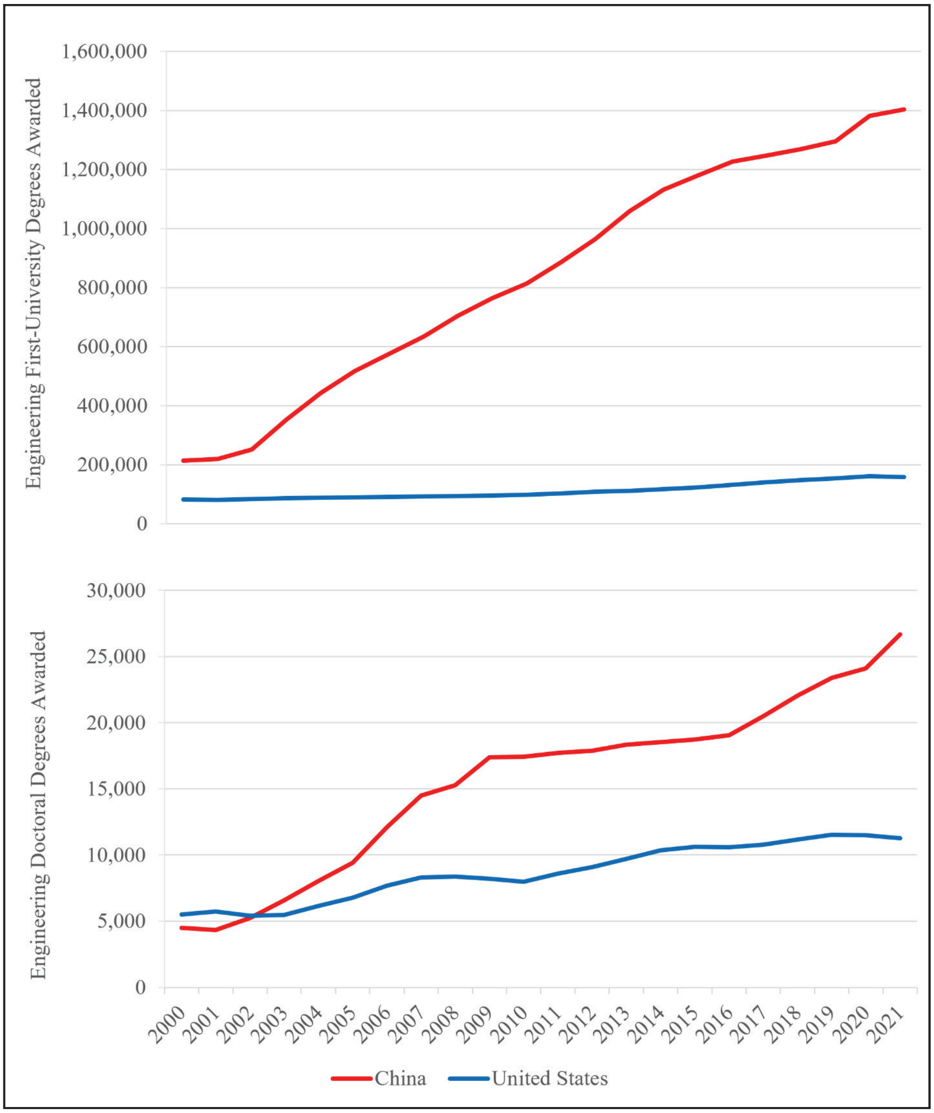


FIGURE 1 First University & Doctoral Degrees in Engineering: China v. USA. China data include computer sciences under engineering. Engineering includes engineering and engineering trades, manufacturing and processing, and architecture and construction. To facilitate international comparison, data for the United States reflect the most recent classification in the International Standard Classification of Education Fields of Education and Training (ISCED-F), which varies slightly from the National Science Foundation's classification of fields presented in other sections of the report. Data for doctoral degrees use ISCED 2011 level 8.

were 3.5 million individuals (2.3% of the total workforce) employed in what is commonly identified as the *engineering* workforce. However, this definition, too, is very broad, including architects, agricultural engineers, technicians, surveyors, sales, etc. Wherever possible, the present article uses a stricter definition of "engineering" and, as such, includes about two million people in the "engineering profession," or about 1.1% of the nation's total workforce. When other broader definitions are used herein, it is because of the lack of relevant data pertaining to the narrower definition; in such cases, the use of an alternative definition is indicated.

The domestic pipeline for producing engineers can only be described as extremely leaky. About 87% of all ninth graders ultimately earn a high school diploma. Of those who do, only 62% will enter college, and of those who enter college, only 11% will declare an engineering major. But only a net 50% of the latter will graduate with a degree in engineering. And of those securing a baccalaureate in engineering, only 4% will eventually receive a doctorate in the field. Stated otherwise, to produce a single bachelor's-level engineer working in the field in 2032 requires a pool of about 20 US ninth graders today, and to produce a doctorate engineer circa 2037 requires a pool of some 400 US ninth graders.

Further, engineering has been identified as an effectual undergraduate preparation for the pursuit of many other professions. According to the US Census Bureau, individuals with baccalaureates in engineering are currently filling 47,300 positions in judicial professions, 118,900 in healthcare, and 819,700 in management, business, and financial fields—about half as many as are pursuing careers in engineering, per se.

The Gap

In 1978, the year of my first visit to China, I observed many thousands of bicycles, a few dozen automobiles, one television set, and enormous crowds of men and women *all* wearing Mao suits. Apparently having been told that

Westerners were wealthy, a question I was occasionally asked by passersby was, "How many bicycles do you own?"

Fast forward to 2014. A momentous event took place that year that went almost unnoticed in the United States: China's GDP at purchasing power parity *surpassed* that of the United States. Calculated at economic exchange rates, China's GDP has continued to gain on that of the United States. Over the years China's leaders, many of whom were engineers, saw to it that the number of PhD's awarded in engineering in 2023 was 34% of all PhD's granted in China—as compared with 19% in the United States (and of the latter, 58% were earned by foreign-born individuals). The current fraction of all first degrees that are awarded in the field of engineering ranks America in 76th place among nations, just behind Mozambique. In 2021 some 6% of baccalaureate degrees from US universities were awarded in engineering—the same as in the field of psychology.

Between 1996 and 2018, China's share of articles among those in the top one percent of cited scientific publications increased by a factor of four. Between 2000 and 2023, America's World Competitiveness Ranking dropped from first to eighth place—all concurrent with the impact of science and technology burgeoning. Reflecting this, between 2008 and 2023, the number of US firms in the Global Fortune 500 fell from 153 to 136, while China's representation increased from 29 to 135. And since the year 2000, China has increased its spending on R&D as a fraction of GDP from 0.9% to 2.6%, while the US R&D intensity has increased from 2.6% in 2011 to 3.5% today.

While China is not without its share of challenges, including a declining and aging population and slowing growth of its economy, its embrace of science and engineering as part of the solution remains largely unquestioned.

Opportunity Knocks

The percent representation of various self-identifying groups (irrespective of place of birth) in the US 2021 overall workforce, followed by the percent representation in the engineering workforce, is as follows: White male—33/60; White female—29/9.0; Black male—5.0/4.0; Black female—6.0/1.0; Hispanic male—10.0/8.0; Hispanic female—8.0/2.0; Asian male—3.4/10.5; and Asian female—3.1/2.8.

In most of the above groupings the evidence displays a substantial underrepresentation in engineering, thereby offering significant opportunities for enhancing America's overall engineering capabilities—albeit over the longer term, given that it takes many years to produce an engineer.

Table 1 indicates the potential impact of attracting more women and minorities into the engineering profession. Were the representation in engineering of the identified groups to equal that of the same group's cur-

TABLE 1 Potential Gains in Engineers from Represented Groups, %

Race/Ethnicity: Sex	% of U.S. Population	% of the Overall Workforce	% of Engineering Workforce	Potential % Increase in Engineering Workforce	
				Same % of U.S Population	Same % of Overall Workforce
White	60.0	62.0	69.0	—	—
Male	30.0	33.0	60.0	—	—
Female	30.0	29.0	9.0	21.0	20.0
Hispanic or Latino	18.5	18.0	10.0	8.5	8.0
Male	9.5	10.0	8.0	1.5	2.0
Female	9.0	8.0	2.0	7.0	6.0
Black or African American	12.0	11.0	5.0	7.0	6.0
Male	5.9	5.0	4.0	1.9	1.0
Female	6.1	6.0	1.0	5.1	5.0
Asian or Pacific Islander	6.0	6.5	13.3	—	—
Male	2.9	3.4	10.5	—	—
Female	3.1	3.1	2.8	—	0.03

Source: Census—ACS (2021)

rent participation in the nation's overall workforce, an increase of 630,000 engineers (35%) would result. (The two groups that are currently providing proportionately more engineers than their overall representation in the US workforce, Asian males and White males, are displayed based on their current level of participation in the engineering workforce.)

While there are obviously numerous practicable issues to be considered in reaching the outcomes shown, as will be addressed in a subsequent section, the calculation does indicate the enormity of the potential engineering contribution that could be available to the nation by increasingly benefitting from the talents of all parts of its populace. An example is the growth realized in the United States in the participation rate of women in engineering over the past half-century, albeit still grossly underrepresented. Fifty years ago White women represented 3% of the engineering population in the United States as compared with 9% today. If even that modest growth rate were to be sustained, by 2077, the fraction of US women in engineering would equal the female share of today's *overall* workforce (29%). The possibility of a substantial increase in the participation of women in engineering is supported by the facts that currently 56% of law degrees, 54% of medical degrees, and 58% of all bachelor's degrees are earned by women—the latter indicating a nearly 40% disparity of women over men.

The urgency of addressing such issues is reinforced by the projection that the 2060 US population will display a decrease in the fraction of White males (the group that currently provides the most engineers) from 30% to 22%, while the current minority (non-White) workforce will grow from 35% to 53% of the total population.

Opportunity Knocks Twice

The question arises of how the United States has been able to sustain its technological superiority in recent decades when producing such a limited supply of engineers (and scientists). A significant part of the answer has been America's ability to attract large numbers of highly capable foreign-born individuals, particularly to its graduate schools, many of whom remain in the United States, raise families in the United States, and contribute significantly to the nation's economy and overall wellbeing. Fully 29% of the science and engineering faculty at US universities today is foreign-born, as is 30% of the overall science and engineering workforce, along with 36% of America's Nobel Prize recipients this century in chemistry, physics, and medicine (a share that was 50% in 2019). Similarly, 45% of the US Fortune 500 firms had a founder who was an immigrant or a child of an immigrant. Among the top third of Fortune 500 firms, that share was 57%.

In 2021, 56% of the doctorate-level engineering workforce was foreign-born, as were 32% at the master's level and 14% at the bachelor's level. This corresponds to a share increase at the doctorate level over the past 30 years from 27% to 56%. The number of international graduate students in US higher education has accordingly increased from 280,000 in 2012 to 470,000 in 2022, the latter marking a 37% recovery since the trough encountered during the Covid pandemic.

At the doctorate level in 2022, 32% of international students came from China and 15% from India. At the overall tertiary level the fraction of students from China has declined during the past two years from 35% to 27%, while those from India increased from 18% to 26%. Ninety-six percent of the doctorates awarded by US universities to students from China are in the fields of science and engineering, as compared with 44% for US-born students (9.4% specifically in engineering). A recent international survey found that if individuals across the globe were required to leave their home country, 57% would choose to go to the United States—and 9% to China.

Among Chinese-born doctoral recipients in science and engineering, the stay rate has declined from 95% following the Department of Justice's "China Initiative," which was promulgated in 2018 and addressed such topics as economic espionage, but remains at about 83% today. Concerns have periodically been expressed over China's propensity to place spies among its international students. Clearly, this is a serious matter and ample precautions are warranted. Almost all research conducted at US universities is openly published, and, in balance, contributions of foreign nationals to the United States, including those from China, have been immense.

It can comfortably be asserted that America's engineering (and science) enterprise would hardly function today were it not for the contribution of foreign-born individuals. Regarding the future, between 2016 and 2060 the foreign-born proportion of the US population is projected to increase from 44 million to 69 million individuals, from 14% to 17% of the then current population (400 million), making the above consideration even more consequential. Clearly, one of America's greatest defining resources over the years has been the diversity of its population, both domestic and foreign-born.

Impedances

If America is to benefit from the opportunities cited herein, it cannot continue on the unsustainable path it has been pursuing in recent decades. Needed changes largely fall into three categories: improving America's pre-K–12 educational system; ensuring that funding is available to exploit the opportunities that are accessible through a larger number of engineers (and scientists); and eschewing counterproductive government policies.

These observations are not uncommon, but, unfortunately, they have commonly been ignored. Forty years ago the seminal report, *A Nation at Risk*, addressing America's K–12 education system, concluded that "if an unfriendly foreign power had attempted to impose on America the mediocre (K–12) educational performance that exists today, we might have viewed it as an act of war." Similarly, the Hart/Rudman study of national security conducted 20 years ago opined that "second only to a weapon of mass destruction detonating on an American city, we can think of nothing more dangerous than a failure to manage properly science, technology and education for the common good." The *Gathering Storm*[3] report on America's competitiveness some 15 years ago noted that "without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position."

Arguably, the greatest single barrier to transforming into reality the opportunities that lie before the nation resides in its pre-K–12 public education system—which by almost any measure must be adjudged as globally *noncompetitive*. In the well-regarded international PISA test of the educational achievement of 15-year-olds, the United States ranks 16th in science and 34th in math, the latter just ahead of Slovenia and Croatia. In the United States' own test of educational achievement, the NAEP, often referred to as "The Nation's Report Card," 76% of 12th graders are not proficient in math and 78% in science. In fourth grade, 59% are not proficient in math and 62% in science, a regression of 17 and 16 percentage points, respectively, following the intervening eight years of exposure to the educational system.

On an average school day in America, 7,000 students drop out of high school. In the nation's capital, 37% of students are categorized as "chronically truant," an improvement from 42% the prior year. A student in China receiving a high school diploma will have had at least three more years of classroom education than his or her counterpart in the United States, simply because of the difference in the number of school days in the school year and class hours in the school day in the respective countries.

Adding to these already formidable challenges, various studies have shown that when a child from the lower 10th percentile of US families by wealth appears for the first day of pre-school, they will have heard literally millions fewer spoken words than a child from the upper 10th percentile. Overcoming such disparity represents a monumental task for the nation's educational system and for US society as a whole.

Arguably, the greatest single barrier to transforming into reality the opportunities that lie before the nation resides in its pre-K–12 public education system.

Ironically, at $19,300 the United States ranks second, behind Luxembourg, among OECD nations in spending per primary and secondary student. Since 2000, public school enrollment has increased by 8%, while administrative costs have accelerated by 88%, and academic performance has largely remained unchanged.

Highlighting a rather dubious development, the high school four-year graduation rate remained relatively stable at 72% over the 30 years between 1980 and 2010, then in the 13 years between 2010 and 2023 suddenly escalated to 85%. An *Economist* magazine study of 3,000 US schools recently concluded that in 2007 about half of US students in the bottom 10% of ACT/SAT scores graduated from high school, whereas by 2022 two-thirds of that same group had graduated. The inference is indeed troublesome and is echoed by the lowering of academic standards by a number of states and school districts. According to the Department of Education, 40% of those currently accepted into four-year colleges are required to take at least one remedial education course, half of whom never receive a degree.

The situation in American *higher* education could hardly offer greater contrast. The *Times* of London

[3] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2007. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, DC: The National Academies Press.

globally ranks US universities in three of the top five places, and 16 of the top 25, in its world ranking of universities. While rising tuition (including net tuition) at the nation's higher education institutions is a major concern, one of the nation's greatest assets is its system of public and private colleges and universities.

Turning to the second major challenge, increasing the number of engineers without increasing investment in R&D could well prove to be counterproductive.

In 1969, the US share of world R&D expenditures was 69%; today it is 31%. The nation is largely dependent on government funding for large, high-risk/high-return, long-term projects. In terms of government ranking in R&D intensity (R&D as a fraction of GDP), the United States has fallen from first to 13th place among nations. Federal support for R&D as a fraction of GDP has dropped in 22 of the past 28 years. The United States ranks 24th among 36 OECD nations in the share of basic research that is funded by the government. Correspondingly, the government-funded share of US R&D has dropped from two-thirds to about one-fifth (21%) in 50 years. In 2024, China announced an increase in its science and technology investment of 10%—at about the same time the United States announced an 8.3% *decrease* in the National Science Foundation budget. Meanwhile, US industry, once home to mighty research facilities such as the canonical Bell Labs, has increasingly focused on short-term financial results. When I first entered industry in 1957, shareholders held their stock for an average of eight years; today that period is five months.

But an even greater concern is the Congressional Budget Office's forecast that the non-discretionary portion of the federal budget, as compared with projected federal revenues, both under current law, will gradually squeeze the discretionary portion of the budget (infrastructure, national security, R&D, etc.) to *zero* within a little over a decade—making the competition for federal R&D funding literally existential. Addressing this issue through major cuts in social programs or major tax increases will, to say the least, be formidable; and doing so through increased borrowing will be counterproductive, as suggested by the fact that interest payments on the federal debt have already surpassed the nation's spending on national security and are projected to continue to increase substantially as the nation drifts toward a forecast 122% debt to GDP ratio a decade hence. During this period national security spending is forecast to decline from 2.9% of GDP to 2.5%.

Finally, turning to the impact of public policy on the nation's engineering and scientific capability, the states have reduced spending on public higher education, where 70% of the nation's students are educated, by $5.7B since 2019 in inflation-adjusted dollars, while educating 800,000 more students. Meanwhile, the federal government has imposed a new (albeit *thus-far* modest) tax on the endowment gains of a few of America's most highly regarded universities, thereby absorbing funds that could have been devoted to financial aid or research, all while deterring future donors.

Additionally, the one-year federal budget cycle continues to be fundamentally incompatible with the long-term character of science and engineering endeavors, especially when, during 36 of the past 47 years, the federal R&D budget was not even passed until well into the execution year. Under such circumstances project leaders may not be aware of their budget for a given year until that year is half over, making spending decisions perilous. This persists even after Congress, some years ago, "slipped the definition" of the fiscal year by three months because it was unable to keep up with the old definition.

Also in the policy sphere, a major impediment imposed on foreign students who wish to attend America's universities is the legislated limitation on student visas. An even more punitive impact on US science and engineering capability is the prolonged processing period for green cards sought by those wishing to legally remain in and contribute to the United States after receiving their degrees.

A Win/Win

America's demand for the additional engineers it will need if it is to remain competitive in providing its citizens a high quality of life, including economic security and national security, can be partially met by attracting and enabling a far greater share of US women and underrepresented groups to pursue careers in engineering. But this can only occur if major enhancements are made in the quality of pre-K–12 education, funding of R&D, and public policy. Taking these needed steps would enhance the lives of thousands of citizens through the rewards of a career devoted to solving important national and global problems and, at the same time, offer a median lifetime income that is more than twice that of the overall workforce.

As to the transformative issue of how to overcome the barriers that stand in the way of such an outcome, the National Academies' *Gathering Storm* report offers a reasonable starting point.

The author wishes to thank *Luis Delgado, NAE Christine Mirzayan Science & Technology Policy Fellow from Penn State University, for his significant contributions in researching this article.*

Further Reading

American Society for Engineering Education. 2020. Engineering and Engineering Technology by the Numbers 2019. Washington, DC.

American Society for Engineering Education. By the numbers. Institute for Research and Analytics. Online at https://ira.asee.org/by-the-numbers/.

Anderson G, and Moris F. 2023. Federally funded R&D declines as a share of GDP and total R&D. National Science Foundation, June 13. Online at ncses.nsf.gov/pubs/nsf23339.

Association of American Medical Colleges. 2019. The majority of U.S. medical students are women, new data show, Dec 9.

Atkinson RD, Gawora K. 2021. U.S. university R&D funding falls further behind OECD peers. Innovation Technology and Innovation Foundation, April 12.

Augustine NR, Mamidala S. 2023. Engineers: The boardroom's missing link? Directors & Boards, July 19.

Boroush M, Guci L. 2022. Research and Development: U.S. trends and international comparisons. National Science Board, National Science Foundation. Alexandria, Virginia.

Boundless. 2023. Immigrants have won 40% of Nobel prizes awarded to Americans since 2000, Oct 5.

Committee on New Models for US Science & Technology Policy (Augustine NR, Lane N, co-chairs). The Perils of Complacency, Restoring the Foundation: The Vital Role of Research in Preserving the American Dream. American Academy of Arts & Sciences. Cambridge, Massachusetts.

Congressional Research Service. 2022. Global Research and Development expenditures: Fact sheet. R44283. Online at https://sgp.fas.org/crs/misc/R44283.pdf.

Deitz S, Freyman C. 2024. Science & Engineering Indicators 2024: The State of U.S. Science and Engineering. National Science Board, National Science Foundation. Alexandria, Virginia. Online at https://ncses.nsf.gov/pubs/nsb20243.

Deitz S, Henke R. 2023. Higher Education in Science and Engineering. NSB-2023-32. National Science Board, National Science Foundation. Alexandria, Virginia. Online at https://ncses.nsf.gov/pubs/nsb202332/characteristics-of-s-e-degree-recipients.

The Economist. 2024. New numbers show falling standards in American high schools, March 10.

Enjuris. 2018. Law school rankings by female enrollment, Dec 16. https://www.enjuris.com/students/law-school-female-enrollment-2018/.

Evans KM, Matthews KRW, Hazan G, Kamepalli S. 2021. U.S. Federal Scientific Research and Development: Budget Overview and Outlook. Baker Institute for Public Policy. Houston.

Flanigan R. 2024. Engineering student quit, but there's retention tactics. American Society of Mechanical Engineers, April 10.

Fortune. 2023. Global 500. Online at fortune.com/ranking/global500/.

Hanson M. 2024. U.S. Public Education Spending Statistics. Education Data Initiative, July 14. Online at https://educationdata.org/public-education-spending-statistics.

Hathaway I. 2017. Almost half of Fortune 500 companies were founded by American immigrants or their children. Brookings, Dec 4.

Kan Q. 2019. A brief introduction to the Chinese education system. The Open University, Aug 30.

Law.com. 2024. 17 of the top 20 law schools have more women enrolled, Feb 2.

Lindner J. 2024. High school dropout statistics: Impact on students and society. GitNux, July 17.

Martinez A, Christnacht C. 2021. Women are nearly half of U.S. workforce but only 27% of STEM workers. US Census Bureau, Jan 26.

National Academy of Engineering. 2018. Understanding the Educational and Career Pathways of Engineers. Washington, DC: The National Academies Press.

National Center for Education Statistics. Digest of Education Statistics. Online at https://nces.ed.gov/programs/digest/.

National Center for Education Statistics. Fast Facts. Online at https://nces.ed.gov/FastFacts/.

National Center for Education Statistics. Undergraduate Degree Fields. nces.ed.gov/programs/coe/indicator/cta.

National Center for Science and Engineering Statistics. 2023. Doctorate Recipients from U.S. Universities: 2022. NSF 24-300. National Science Foundation. Alexandria, Virginia. Online at ncses.nsf.gov/pubs/nsf24300/report/about-this-report.

National Center for Science and Engineering Statistics. Doctorate Recipients from U.S. Universities: 2020. NSF 22-300. National Science Foundation. Alexandria, Virginia. Online at ncses.nsf.gov/pubs/nsf22300/report/u-s-doctorate-awards.

National Science Board. 2015. Revisiting the STEM Workforce, A Companion to Science and Engineering Indicators 2014. The National Science Foundation. Alexandria, Virginia.

National Science Board. 2018. Higher education in science and engineering. In: Science and Engineering Indicators 2018. NSB-2018-1. National Science Foundation. Alexandria, Virginia. Online at www.nsf.gov/statistics/2018/nsb20181/

report/sections/higher-education-in-science-and-engineering/undergraduate-education-enrollment-and-degrees-in-the-united-states.

National Science Board. 2020. Foreign-born students and workers in the U.S. science and Engineering enterprise. Online at www.nsf.gov/nsb/sei/one-pagers/Foreign-Born.pdf.

The Nation's Report Card. NAEP Mathematics: National Achievement-Level Results. Online at https://www.nationsreportcard.gov/mathematics/nation/achievement/

NEA Research and ASA Research. 2022. Higher Ed State Funding Report. Washington, DC. Online at www.nea.org/he_funding_report.

Richter F. 2023. U.S. loses ground in world competitiveness ranking. Statista Daily Data, June 18.

Science's News Staff. 2024. Final U.S. spending bills offer gloomy outlook for science. Science, March 4.

Society of Women Engineers. Job Outlook for Engineers. Online at swe.org/research/2024/job-outlook/.

Times Higher Education. 2024. World University Rankings 2024. Online at https://www.timeshighereducation.com/world-university-rankings/2024/world-ranking.

Trapani J, and Hale K. 2019. Higher Education in Science and Engineering. The National Science Foundation. Online at ncses.nsf.gov/pubs/nsb20197/international-s-e-higher-education.

US Bureau of Labor Statistics. 2024. Occupational projections and worker characteristics, April 17. Online at www.bls.gov/emp/tables/occupational-projections-and-characteristics.htm.

US Census Bureau. 2021. 2021 American Community =Survey Public Use Microdata Sample (PUMS). Retrieved from https://usa.ipums.org/usa/.

US Department of Education, National Center for Education Statistics. 2022. Preprimary, elementary, and secondary education participation. In: The Condition of Education. Online at https://nces.ed.gov/programs/coe/pdf/2022/cne_508.pdf.

Vespa J, Medina L, Armstrong DM. 2018. Demographic turning points for the United States: Population projections for 2020 to 2060, Population Estimates and Projections. Report P25-1144. US Census Bureau. Suitland, Maryland.

World Population Review. PISA scores by country 2024. Online at worldpopulationreview.com/country-rankings/pisa-scores-by-country.

Zimmermann A. 2023. U.S. R&D and innovation in a global context: The 2023 data update. American Association for the Advancement of Science, April 25. https://www.aaas.org/news/us-rd-and-innovation-global-context-2023-data-update.

Leaders must overcome the obstacles to innovation by seeking inspiration from new perspectives and engaging those that might open them to new ideas.

Unlocking Hidden Value for Inclusive Innovation:

The Real Power of Diversity, Equity, and Inclusion

Nicholas M. Donofrio (NAE) is CEO, NMD Consulting, LLC.

Nicholas M. Donofrio

How many times have you chosen an approach to solving a real-world problem that needed mid-course correction? After all, most real-world problems vary in degree from those "textbook-closed" solutions you may recall. This is the real world, and it conforms only to itself. You make some assumptions and approximations, and you pick a path forward. You start to feel good about it only to realize you are going in the wrong direction. You stop and look around. You second-guess your assumptions, approximations, and approach. You ask trusted colleagues and known experts for help. They show you the errors in your ways, and with their advice and counsel, you move forward. Bingo—it becomes obvious where you went wrong and even more obvious why their suggestions were so right. Success is yours.

Over and over again we find that real and lasting value is created faster and more completely when we start with the problem and enable the most inclusive, open, collaborative, multidisciplined environment possible to innovate as intrapreneurs or entrepreneurs.

The theory of how to effectively create real and lasting value has been documented by many in many different ways. From 2003 to 2007, I was fortunate to be part of the team that created the National Innovation Initiative (NII) for the USA Council on Competitiveness (CoC). The CoC released the report, *Innovate America: Thriving in a World of Challenge and Change*, in 2005. In 2007 that report served as the basis for the America Competes Act. The document

FIGURE 1 1935 IBM First Systems Service Women. Courtesy: IBM.

remains on the CoC's website as a testament to its lessons learned and taught.[1]

Open, collaborative, multidisciplined, inclusive. As defined by this highly mixed and integrated team of business, technical, academic, and government colleagues I worked with on the NII, here is what we meant by each term:

- "Open" meant open-minded and without bias.
- "Collaborative" meant having a willingness to engage and to learn while teaching and communicating by listening as well as speaking.
- "Multidisciplined" meant bringing together all sources and aspects of knowledge required.
- "Inclusive" meant just that! Bring everyone and anyone who could contribute to the solution into the group, no matter who they were or where they were.

Enabling innovation this way and expanding on it has also been documented by Frans Johansson in his thoughtful and entertaining book, *The Medici Effect* (2004). Time and again the value you seek is there for everyone to see, but only true innovators unlock that hidden value sooner and more completely than others, as Johansson repeatedly points out.

Yet we constantly debate, discuss, and defer when we know better. How do you know who does and who does not hold the last piece to a puzzle you are focused on solving? How do you know a priori whom to leave out and whom to include?

Perhaps it is our fear of change that keeps us focused on only like-minded colleagues.

Perhaps it is our fear of differing opinions that may come with differing cultures if we stray too far from our comfortable norm.

Perhaps it is our fear of resolving conflicts of opinion and thought that slows us down to only drive under the orange caution flag.

Somehow and in some way real leaders find a way to reach through these issues to grasp the real value waiting on the other side.

IBM is a case in point. IBM was my employer for 44 years. I learned a great deal from IBM during this time, but I feel like I learned even more by studying what they did before I arrived in 1964 and why they did it. I often wondered: Just how new was this idea of inclusive innovation?

Somehow Tom Watson Sr. figured out back in 1935 that including women in the IBM sales force was going to be a real value creator. How did he figure this out on his own? Was it his wife and daughter who provided the light that he followed, or was it simply his own intuition based on observation and experience? In any case, he got it right and history was made. Including women in the highly, if not exclusively, male-dominated sales workforce and culture was as bold a move as it gets. Being a visionary leader with the courage and conviction to act always matters. I will never forget that graduation picture of an all-women sales class proudly standing in front of the IBM Endicott Education Building (see figure 1). Value creation was enabled as it never had been before.

Perhaps the images painted by stories like the all-women IBM sales class and my own personalization of

[1] The National Innovation Initiative began in 2003 as a multi-year effort engaging hundreds of leaders across the country and from all walks of life to optimize our entire society.

them drove my thinking to be more inclusive in problem solving as I progressed through IBM. But the facts in front of me were also informing my judgement and actions. The lack of women in technical circles was painfully obvious to me. But even more obvious to me was the lack of people of color. How do you know you have the best possible answers to the problems you are facing when everyone in the room looks like you? Clearly the talent base was biased, and, unless we intervened, nothing was going to change. IBM enabled me to engage where, when, and as I felt necessary. The National Action Council for Minorities in Engineering (NACME), the National Society for Black Engineers, the Black Engineer of the Year, the Society of Hispanic Professional Engineers, the Society of Women Engineers, and the American Indian Science and Engineering Society, among other organizations, became my focus and, in some sense, my passion. Pathways to innovation could only be enabled by pathways to success for an increasingly diverse technical community. I engaged then and remain engaged now in enabling these pathways to become broader and faster.

All of this thinking was clearly front and center when I led the IBM engagement with the CoC to help write the NII report (circa 2003–07). Its principles of innovation are simple, logical, and perhaps mundanely obvious. First, always start with the problem and not the answer. Second, the hidden innovative value that all are in search of is hiding in plain sight for all to see. Third, unlocking that hidden value is best done by enabling an environment that is open, collaborative, multi-disciplined, broad-based, and broad-minded—in short, inclusive—for the simple reason that, a priori, you just do not know who has the missing piece to the puzzle you are trying to solve.

As a lifelong learner, I have also come to appreciate change and the need to embrace it. As an engineer, I understand that becoming comfortable with a steady state limits your ability to seek, find, and create real and lasting value.

I remember it as if it were yesterday. When I first looked around the conference room to see who was working with me on one of the early IBM semiconductor chip designs, I noticed that it was only people who looked like me. At every problem, and there were many, I wondered if the people who were missing already had the answer. These thoughts stayed with me as I grew. As a leader I knew what I needed to do: focus on change and making a difference. Engage with all the communities who were not in the room, find out why they were not present, and then do something about it. Ted Childs was my partner and guiding light from the start. IBM actually understood this as well. They joined NACME soon after it was created. Following two IBM CEOs on the NACME Board as a young engineer was not easy. Ted coached me and mentored me. I served on NACME's board for 20 years and chaired it for my last five. I felt and knew I was making a difference by helping fill those design conference rooms around the country with people who did not look like me. I recruited our beloved colleague **John Brooks Slaughter** to become the CEO of NACME. John and I worked together to continue to change the rate and pace of progress, realizing full well that we were not making the difference that mattered fast enough. John mentored me, and I coached John while Ted instructed us both as we engaged together to bring about change quicker.

> ***Being a visionary leader with the courage and conviction to act always matters.***

Adalio Sanchez (another one of our NAE colleagues) and Ted helped me focus on the Society of Hispanic Professional Engineers. We engaged and committed ourselves to supporting their wide-ranging chapter network.

With Linda Sanford's assistance (yes, she too is one of our NAE colleagues) and Ted's guidance, we also engaged with the Society of Women Engineers and their equally wide-ranging network.

Rod Adkins (another one of our NAE colleagues), Ted, and I also committed ourselves to the National Society of Black Engineers for even more access to students through their vast chapter network.

The formula for success here was always the same: Engage early, thoughtfully commit your time and resources, and deliver against your commitments. And stay engaged!

Together we made an incredible difference that mattered for IBM and for the country.

As much as Linda, Rod, and Adalio were my proteges, we were also colleagues. They taught me likely more than I taught them.

We used the collaborative and inclusive innovation model to create real and lasting value for IBM while we were all together resurrecting IBM's system business from its own ashes or working together after IBM on many businesses, new and old, large and small, public and private, NGO and for profit.

The model of inclusive innovation is tried and true and battle hardened. The logic is simple; the commitment is not. It is a matter of leadership and willingness to change. And, as we have learned, technology becomes an ally in support of the model, especially in times of intense change.

The COVID pandemic taught us all that work and work environments are not simply physical or digital, but actually a spectrum of possibilities everywhere in between. Innovation and creativity did not stop because of COVID. Networks of talented problem solvers were enabled to become more diverse, open, and inclusive. Diversity, equity, and inclusion (DEI) started to take on new meaning. Global reach became commonplace, only separated by time. Distance no longer mattered. Multi-disciplined took on new meaning since no skill was beyond reach. And the base of openness and collaboration took on ever-growing meaning as it became increasingly self-evident that what we meant was less discrete and more of a continuum. While gender is the most obvious example, the same is true of ethnicity, religion, race, nationality, intelligence, age, ability, and everything to come.

DEI means "every one" and not just "some ones."

Since we truly do not know who has that missing piece to solve incredibly critical puzzles, the odds of success rise rapidly when all who are able are welcomed and enabled.

References

CoC [Council on Competitiveness]. 2005. Innovate America: Thriving in a World of Challenge and Change. Washington, DC.

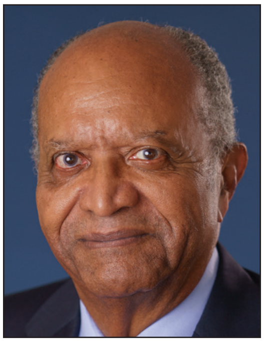
Johansson F. 2004. The Medici Effect: Breakthrough Insights at the Intersection of Ideas, Concepts, and Cultures. Brighton, MA: Harvard Business Review Press.

Looking back at the history of the minority engineering effort offers an example of how, with strong leadership, a seemingly intractable problem can be solved with a systems approach.

The 50-Year History of the Minority Engineering Effort:

How the Engineering Profession Sparked the Movement to Diversify Its Workforce

Percy A. Pierre and
Catherine J. Weinberger



Percy A. Pierre

Catherine J. Weinberger

Fifty years ago, major private US institutions came together to help solve a problem that none of them could solve alone. Spurred by the civil rights movement of the 1960s and the new affirmative action mandates of the Nixon administration in 1971, they formed a collaboration to increase the number of minority engineering graduates. Prior to that, each organization had its own programs to contribute to the solution of this national problem. They found that this approach was not working.

At that time, the focus was on African American engineering graduates. Between the 1968–69 and 1970–71 academic years—the first three years of systematically counting new engineers by race—the number of new African American bachelor's degree graduates in engineering grew from 314 to 407, and more than half of those graduated from one of the six historically Black engineering programs (Pierre 1973; Weinberger 2018). This changed rapidly after the minority engineering effort began. By the early 1980s, the number of bachelor's degree graduates had grown to about 2,000 per year, reaching 3,000 per year by 1995. Recent annual estimates are in the 5,000–6,000 range for

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bachelor's degrees, over 1000 for master's degrees, and over 150 for PhDs, compared to 314 bachelor's degrees, 17 master's degrees, and two PhDs in 1969. Trends since 1995 are discussed in the following article, "Does the Minority Engineering Effort Have a Flat Tire?," while this piece is focused on the story behind the remarkable, nearly tenfold growth in African American bachelor's degree graduates in engineering between 1970 and 1995.

Recent years reflect a holding pattern. Published statistics describe a flatlined proportion of new engineering graduates who are African American.[1] During the first 30 years of the minority engineering effort, this statistic rose from less than 1% to 5.5% before declining. Over the past decade it has stabilized at a bit over 4%.

An understanding of the history of the minority engineering effort provides lessons on how we might move forward. The minority engineering effort is an example of how, with strong leadership, a seemingly intractable problem can be solved with a systems approach.

The following describes how, beginning in 1972, General Electric (GE), the National Academy of Engineering (NAE), and the Alfred P. Sloan Foundation came together to form an effective minority engineering effort. Each of these three organizations moved out of its comfort zone to do something together that it could not have done alone. They decided that it was not sufficient to simply contribute to a solution; it was necessary to take responsibility for results on a national scale. The success of this effort was enhanced by close collaboration, and also by the ability of engineers in leadership roles to employ a systems engineering approach. The strategy that evolved included leadership from CEO-level executives of industry and universities, a strategic and systemic analysis of the problem at all levels of the educational pipeline to identify areas for the most impactful interventions, a program design strategy that maximized the national impact, and a funding strategy designed to elicit long-term funding from industry, universities, and government entities. The key leaders of the minority engineering effort at that time were Reginald Jones, chairman of GE, Robert Seamans, president of the NAE, and Robert Kriedler, executive vice president of the Sloan Foundation.[2] That effort helped create many of the minority engineering programs that are, or will soon be, celebrating their 50th anniversaries.

Today, we are facing a problem with minority engineering education similar to the problem that presented itself in the 1970s. Individual actors are making contributions, but the results fall far short of what is needed.

Planning and Collaboration

The GE Initiative

In 1972, Percy Pierre—who was then the dean of engineering at Howard University—received an invitation from GE to attend a meeting at their Crotonville, New York, Education Center. GE was a leading employer of engineers. Like other companies, GE made contributions to engineering schools to help them in the production of engineers, including minority engineers. GE recognized that this approach was not working for minority students. At the meeting, Stanley Smith, senior VP of GE, gave a presentation on the need for more minority engineering graduates, largely based on a strategic analysis of the engineering educational system and its production of minority engineers. This study was led by Lindon Saline, VP of GE and director of the GE Education Center, where the meeting was held. Also in attendance were Fred Borch, the CEO of GE at the time, Edward David Jr., director of the White House Office of Science and Technology, and a select number of US deans of engineering. Many of the attendees later played active roles in the implementation of the minority engineering effort. For example, Smith was the founding chair of the Board of the National Scholarship Fund for Minority Engineering Students, which still exists as part of the National Action Council for Minorities in Engineering (NACME), and Fred Borch was one of the founders of the Business Roundtable, a CEO-led business group advocating for industry whose members later provided essential funding to the effort.

Those in attendance learned that GE, and companies like it, had difficulty hiring minority engineers as required by the new affirmative action mandate of the Nixon administration. Assuming that the primary barrier was financial, GE had approached other engineering companies and offered to lead a collaborative effort to produce more African American engineers by providing financial support through scholarships and a program of cooperative education in which students would work half time and go to school half time.

During the discussion that followed Smith's speech, Pierre expressed appreciation for the fact that companies were willing to come together to help solve this prob-

[1] See https://ira.asee.org/by-the-numbers/ and https://undark.org/2020/09/11/after-years-of-gains-black-stem-representation-is-falling-why/.

[2] GE acknowledges the leadership that Reginald Jones provided for minorities in engineering as a highlight of its more than 150-year history. See www.ge.com/ge-history.

lem. He then raised the concern that too few African American high school graduates were knowledgeable of and prepared for engineering study, and that a program of college scholarships and work study positions would do no good without attention to the K–12 educational system. His major problem was that he simply did not have enough students to use their support. The room fell silent for a moment before Smith went on to take other questions.

Senator Hubert Humphrey felt Smith's speech was so important that he gave a brief synopsis, addressed to President Nixon; both his comments and the text of Smith's speech (minus reference to cooperative education) were entered into the US Congressional Record (Humphrey 1973).

Bringing the NAE Onboard

About two weeks after the meeting at Crotonville, Saline of GE went to see Pierre. Meanwhile, Saline had consulted with other engineering deans and then conveyed to others at GE that Pierre's concern was widespread. As a result, GE concluded that, while financial aid for minority engineering students was a vital component of the solution, the problem was bigger than that and needed to be addressed beginning with pre-college preparation and throughout the pipeline of engineering education. GE reasoned that, to be successful, GE and other industrial partners could offer funding but would need to find a respected partner organization knowledgeable about engineering education to lead the effort. Reginald Jones assigned Saline the task of finding that organization. After being turned down by a couple of potential partners, Saline asked Pierre to join his quest. The first organization they approached as a pair said no. Next on their list was the National Academy of Engineering.

Saline and Pierre approached Robert Marshall, the chair of the NAE Committee on Education. Saline explained that GE and its industrial partners were ready to fund a national effort to increase the number of minority engineering graduates and outlined what he had in mind: They wanted the NAE to provide leadership in the creation and operation of programs to prepare minority students for careers in engineering, beginning with K–12 students. Marshall was slow to warm up to the idea, and he replied that the NAE charter included being an advisor to the federal government but the NAE did not in general operate programs; it did studies and held meetings on national issues affecting the field of engineering. The NAE, both an honorific organization and an advisory organization, was founded in 1964 to provide the US government with independent advice on national issues involving engineering and technology. With its focus on engineering education, the NAE would go on to be an ideal partner organization in the minority engineering effort.

As Saline and Pierre suggested alternative ideas to Marshall, they noticed that his assistant, Mrs. Jean P. Moore, seemed interested in what they were saying. And when Pierre asked whether it would be possible for the NAE to organize a symposium, she piped up, "Oh yes, we can do that!" Marshall agreed. Reginald Jones of GE followed up with a phone call to Robert Seamans to confirm NAE support of the symposium and elicited a promise to discuss GE's larger vision after the symposium. Mrs. Moore was called on to organize the symposium.

The minority engineering effort is an example of how, with strong leadership, a seemingly intractable problem can be solved with a systems approach.

The NAE Symposium on Minorities in Engineering was held in 1973 (NRC 1973) to review the system of engineering education and the role of minorities in that system. Pierre and Saline agreed that the symposium would be the first step, not the last. Pierre chaired the planning committee for the symposium and gave the opening address. The symposium was attended by 231 representatives of universities, industry, the federal government, and other interested organizations. The symposium presented many recommendations for addressing the problem. It also supported GE's request that the NAE take the lead in this effort by establishing an action-oriented CEO-level advisory committee to the NAE and a working committee that industry would support. That was the next step.

Robert Seamans, who had recently become president of the NAE, was previously the secretary of the US Air Force and, before that, an administrator of NASA. He recognized that the NAE was primarily an organization that did studies. The proposal to improve the K–12 education of minority students on a national scale was very different. The symposium participants and GE wanted more than advice. They also wanted to follow through and create a national leadership organization.

The Establishment of NACME

About a week after the symposium, Bob Seamans asked to meet with Pierre to review the results of the symposium. He had decided to accept the recommendation of the symposium and establish a National Advisory Council on Minorities in Engineering (NACME). Reginald Jones had agreed to chair the committee, bring along his industrial colleagues, and provide financial support to the NAE and to the programs generated by this effort.

Key members of NACME came from attendees of GE's meeting at Crotonville, the Business Roundtable that Jones chaired, presidents of major universities, and government officials. Although this was called an advisory committee, the members of NACME were expected to be active participants in the programs encouraged by NACME. For example, Fr. Theodore Heaburgh, then president of the University of Notre Dame, would later be critical in establishing the GEM Fellowship Program, which offers fellowships to minority engineering students seeking master's degrees.

While the political and legal landscape has changed, what has remained constant is the national need for a large, diverse, and talented engineering workforce.

The NAE announced the creation of NACME in 1973, with its first meeting taking place in January 1974. Later, Reg Jones promised $400,000 per year from GE and its corporate partners to support the NAE's efforts (Miranda and Ruiz 1986). In 2024 dollars, that is nearly $3M per year. This money was to support hiring staff and conducting appropriate studies and meetings. The funds would also support programs created by this effort (Saline 1974).

The NAE also decided to create an internal operational committee, the Committee on Minorities in Engineering, initially chaired by Richard Grosch (Grosch 1974). Later this committee was chaired by Arthur Hansen, then president of Purdue University, and co-chaired by Pierre. Arthur Hansen would later work with his African American engineering students at Purdue in their effort to create the National Society of Black Engineers (NSBE).[3]

Since NACME was a CEO-dominated group, fundraising for NAE support was relatively easy. Reg Jones would usually schedule a NACME meeting on the same day as his meeting of the Business Roundtable that he chaired. He would take a couple hours off his Roundtable meeting to have the NACME meeting, and he would bring along some colleagues from the Business Roundtable meeting. At the NACME meeting, he would go around the table soliciting funds from the corporations present. Surely this was all prearranged, but it was impressive nonetheless.

The Sloan Foundation

After the NAE announced the creation of NACME, the Sloan Foundation, under the leadership of President Nils Wessel, decided to create a special program for minorities in engineering and committed 20–25% of its annual grant funding over five to seven years to this effort. This was a $12M to $15M commitment, worth about $80M to $100M today (Blackwell 198; Lusterman 1979; Pierre 1975, 2015). Robert Kriedler, a VP of the Sloan Foundation, said that without the commitment of industry and the NAE, Sloan would not have done this. He felt the problem was too large for Sloan funds alone to have a meaningful impact.

Sloan had been a supporter of the 1973 Symposium on Minorities in Engineering. One of Sloan's vice presidents, Arthur Singer, attended the symposium and knew the background of the establishment of NACME. The Sloan Foundation had long supported educational efforts for minorities. In the 1960s, they established scholarship programs for minorities in medicine and minorities in master of business administration programs. While they had a longstanding interest in engineering, they decided that, given their limited resources, a scholarship program for minorities in engineering would have limited impact.

Pierre, still the dean of engineering at Howard University at the time, was asked by the Sloan Foundation to become a half-time program officer for the newly

[3] nsbe.org/home/about/

established program. The coalition composed of GE, the Business Roundtable, the NAE, and the Sloan Foundation was in place.

Almost all of the companies of the corporate members of NACME expanded their minority engineering programs. After the Sloan Foundation announced its new program, it received many unsolicited proposals — many from the people who had attended the NAE Symposium on Minorities in Engineering. To fund these proposals would have been business as usual. Rather, Sloan decided to take a systems approach, familiar to Pierre, who had previously worked at the RAND Corporation, which had pioneered this approach to social problems. The first step was a systems analysis. The second step was to fund consortia of organizations to address different parts of the problem. This systems approach was coordinated with the NAE and the industrial partners through NACME.

Almost all of the programs created by the Sloan Foundation assumed industrial funding, which Pierre coordinated with Lindon Saline. Also, the Sloan Foundation supported programs at universities with the understanding that these programs would also receive university funding. Many also received state funding. The understanding was that increasing the number of minority engineering graduates would benefit all participants, so all should contribute to this effort.

A Blueprint for Action

In 1974, the Sloan Foundation had a very good analysis of the problem provided by the GE strategic analysis and the NAE Symposium of Minorities in Engineering. While everyone agreed on the goal of the program, to significantly increase minority engineering graduates, there were questions about whether the goal was financially feasible with the funding currently committed by the Sloan Foundation and industry. To address this question and others, the Sloan Foundation sponsored a study to address the financial feasibility of the effort and, if possible, the design of programs. Lindon Saline was part of this study. When completed, the study was presented to NACME for their comments and suggestions. This is an example of the coordination among the Sloan Foundation, the NAE, and industry.

The study, *A Blueprint for Action*, was led by Louis Padulo, an engineering professor at Stanford University (PCEMOE 1974). Lou led a program at Stanford to graduate minorities with master's degrees in engineering. Previously, while a graduate student at Georgia Tech, he helped create a dual-degree engineering program between the historically Black colleges and universities in Atlanta and Georgia Tech.

A Blueprint for Action laid out the direction that Sloan would take and argued that a significant impact was possible with the funding available from the Sloan Foundation and industry under the assumption that universities and industry would provide additional financial support for the foreseeable future. The study said that priority should be given to pre-college programs while seeking impactful interventions at all points of the engineering educational pipeline including pre-college, college, and graduate school, and Sloan followed those recommendations. As Pierre described in a personal biography, Sloan, wishing to influence as many students as possible, was careful to fund program proposals that they believed would be sustainable even after the initial Sloan funding expired.[4] Sloan had a venture capital approach in supporting high-risk ventures that had the potential to attract many other investors that would sustain the program and have a 50-year impact.

The programs created by this effort, described below, had a significant impact, particularly on increasing the number of African American students in engineering education.

Pre-college Programs

In the early 1970s, very few engineering colleges had access to pre-college programs to recruit minority students. The few that did include Purdue University, the University of Wisconsin, and the University of Alabama. Sloan initiated grants to change that.

- The Big Ten+ Consortium has some of the biggest engineering schools in the country. Some had initiated minority engineering programs. Sloan promised to add funds for a limited time if these schools would work together to greatly expand their engineering pre-college programs. They could also expect funds from industry, for which minorities in engineering had become a high priority. Many of these colleges of engineering established minority engineering offices to manage these programs. Other colleges established similar programs. An indication of the success of this effort was the establishment of a national association of minority program directors called the National Association of Multicultural Engineering Program Advocates (NAMEPA). NAMEPA currently has 28 member institutions.

[4] depts.washington.edu/celtweb/pioneers-wp/?p=571

- The Mathematics, Engineering, and Science Achievement (MESA) program originated as an in-school club at Oakland Tech High School in Oakland, California. It was started by Mary Smith, a math and science teacher at the school, who wanted to encourage more African American students to enroll in her math classes. Engineering faculty at the University of California, Berkeley, worked with her to bring in industrial funding and organize field trips. The faculty at UC Berkeley wanted to expand the program to three other high schools in the Berkeley, California, area. Sloan provided expansion funding. Subsequently, the program spread throughout California and other states with state funding.[5]
- At the request of the Sloan Foundation, Joseph Petit, then president of Georgia Tech, organized the South East Consortium for Minorities in Engineering (SECME) to work with science teachers.[6]
- In 1974, the Houston Independent School District was planning to start a new magnet school focused on technology. Their purpose was to attract more minority students to their very successful group of magnet schools. Sloan convinced them to create a magnet school focused on engineering, the High School for the Engineering Professions, and to place it in the predominantly minority Booker T. Washington High School. Sloan provided a planning grant for the design of the program.[7] Industrial funding followed. The program has continued to graduate minority students well prepared for engineering careers.

College Program

While pre-college was a priority, creating more scholarships for minorities was a necessity, as identified in the GE analysis and *A Blueprint for Action*. The National Scholarship Fund for Minority Engineering Students (NSFMES) was started in 1974. The NAE created a non-profit organization to host the fund. Stanley Smith chaired the non-profit. Pierre served on its board and Sloan funded its administrative needs, with the understanding that all scholarship funds would come from industry. When NACME spun off from the NAE, it incorporated NSFMES into its organization.

Graduate Program

The Sloan Foundation asked Theodore Hesburgh, then president of the University of Notre Dame and a member of NACME, to call a meeting of universities interested in increasing their minority engineering enrollments at the master's level. Also invited were representatives of high-tech companies, including NACME companies, and non-profit defense R&D firms. Arthur Singer and Pierre presented a plan for an organization, Graduate Education for Minorities (GEM), [8] to increase minority engineering graduates at the master's level. It required contributions from all at the meeting. The Sloan Foundation would provide funding for the initial organizations. The companies would provide a partial fellowship and a summer internship at the company. The universities would provide additional funds for a fully funded fellowship. The benefit to all was that GEM would recruit students for this opportunity and greatly increase the number of minority engineering graduates at the master's level. Joseph Hogan, then dean of engineering at Notre Dame, wrote the proposal to Sloan to establish the program at the University of Notre Dame. He led the GEM program until he hired Howard Adams to run it. Ted Hesburg nurtured the program throughout his tenure as president.

Related Activities

In addition to the programs created by the Sloan Foundation, the activities of NACME and its supporting companies spurred many more activities. Almost all of these activities were supported by the companies of NACME.

- The National Society of Black Engineers, founded in 1975. Arthur Hansen—then president of Purdue, a member of NACME, and chair of the Committee on Minorities in Engineering—supported his Black engineering students when they decided to form a local Black engineering society, the Black Society of Engineers, in 1971. These students later founded the National Society of Black Engineers (NSBE).[9] Their annual meetings attract over 15,000 attendees annually.
- The Society of Hispanic Professional Engineers (SHPE), [10] founded in 1974.

[5] See mesausa.org/ and mesausa.org/mesa-history/.

[6] See www.eng.ufl.edu/secme/.

[7] See www.houstonisd.org/domain/22409

[8] https://www.gemfellowship.org/

[9] https://nsbe.org/home/about/

[10] https://shpe.org/about-shpe/the-story-of-shpe/

- MAES, founded in 1974 as Mexican American Engineering Society, now Latinos in Science and Engineering.[11]
- The American Indian Science & Engineering Society,[12] founded in 1977.
- The Society of Women Engineers[13] was founded in 1950 but expanded by an order of magnitude during the 1970s, from 1,100 members in 1970 to 9,600 members (including both women and men) in 1980.

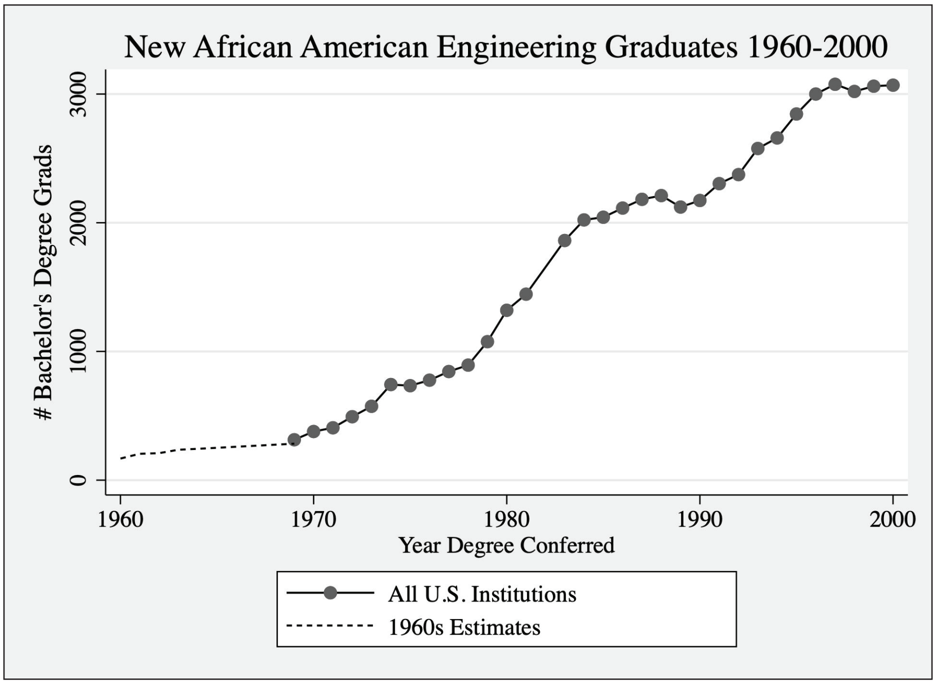

FIGURE 1 The number of degrees plotted at year Y includes new engineering graduates from July of year Y-1 through June of year Y. Point estimates are computed from institution-level IPEDS data published by the US Department of Education (1992/93–1999/2000), and from statistics published by the Engineering Manpower Commission in earlier years. Before 1969, exact numbers were not counted; estimates are based on HBCU total degrees*(1.2), based on earlier estimates that two-thirds of Black engineers were trained at HBCU campuses during that time (Weinberger 2018), and that 80% of HBCU engineering graduates were African American when counting began.

The newly founded organizations and other recommendations of *A Blueprint for Action* took several years to influence new cohorts of engineering graduates. Figure 1 shows growth throughout the 1955–95 interval in the number of new African American engineering bachelor's degree graduates per year, with a sharp increase in slope after the late 1970s as the first cohort to benefit reached college graduation age. Of course, the significant progress depicted in figure 1 cannot all be ascribed to the minority programs started in the 1970s. For example, beginning in the 1980s, the National Science Foundation launched many programs designed to increase minority graduates in the science, technology, engineering, and math fields. Corporations and universities did likewise. However, the discussion initiated by the authors of *A Blueprint for Action* and the subsequent programs launched in the 1970s were a significant impetus for this advance.

Conclusions

In 1972–73, a discussion initiated by GE at its Crotonville Education Center and continued at a symposium hosted by the NAE marked the beginning of the minority engineering effort. Although the titles of both of these initial gatherings used the term minorities, in fact, the focus was on African Americans since the discussion was largely a response to the civil rights movement and affirmative action mandates of the Nixon administration. However, it can be argued that the minority engineering effort—joined by representatives of large engineering employers, the NAE, the Sloan Foundation, academia, and the federal government—and its focus on improving US education systems to fully utilize talent eventually led to national policies that increased the engineering and science representation of other minorities and women.

While we have made great progress over the last 50 years, we still have a long way to go. While the political and legal landscape has changed, what has remained constant is the national need for a large, diverse, and talented engineering workforce. As the US population becomes more diverse, it is even more important that we access the talents of this increasingly diverse population. A recent meeting hosted by the American Association for the Advancement of Science, and funded by Sloan, pro-

[11] https://mymaes.org/about-us/

[12] https://aises.org/

[13] https://swe.org/ and https://alltogether.swe.org/2020/05/celebrating-70-years-of-swe

duced a list of recommendations to help the leadership of individual campuses navigate equity and inclusion in the new legal environment (AAAS 2024). Additional insights might be drawn from the more systemic approach taken by the early visionaries of the minority engineering effort. The lessons of the past can be useful in addressing this national need.

References

AAAS [American Academy of Arts and Sciences]. 2024. Leading for a Future of Higher Education Equity: Transforming Supreme Court Challenges into Opportunities for Positive Change. Cambridge, Massachusetts: American Academy of Arts and Sciences.

Blackwell JE. 1981. Mainstreaming Outsiders: The Production of Black Professionals. Bayside, New York: General Hall.

Grosch RJ. 1974. Report of the committee on minorities in engineering. In: Reports of the Chairmen, NAE Advisory Units, to the Academy Membership: Proceedings of the Technical Session at the Tenth Annual Meeting, May 2 and 3, 1974, 125–27. Washington, DC: The National Academies Press. Online at nap.nationalacademies.org/read/20186/chapter/15.

Humphrey H. 1973. A Tenfold Increase in Minority Engineers—A Civil Rights Challenge for the Seventies. US Congressional Record: Proceedings and Debates of the 93rd Congress, Jan 12, 1973, 1040–43. 93rd Congress, 1st sess., v.119:pt.34 (1973:Jan 3/Dec 22). Washington, DC: US Government Printing Office.

Lusterman S. 1979. Minorities in Engineering: The Corporate Role. New York, NY. The Conference Board.

Miranda L, Ruiz E. 1986. NACME Statistical Report 1986. National Action Council for Minorities in Engineering Inc. New York.

NRC [National Research Council]. 1973. Proceedings of Symposium on Increasing Minority Participation in Engineering. Washington, DC: National Academies Press.

Pierre PA. 1973 Minorities in engineering. In: Minorities in Engineering, Proceedings of a Meeting of the Engineering Manpower Commission of Engineers Joint Council, November 30, 1972. New York: Engineers Joint Council.

Pierre PA. 1975. Keynote address: Minority program directors' workshop. In: Proceedings of a Workshop for Program Directors in Engineering Education of Minorities. Washington, DC: The National Academies Press.

Pierre PA. 2015. A brief history of the collaborative minority engineering effort: A personal account. In: Changing the Face of Engineering: The African American Experience, 13–36. Slaughter JB, Tao Y, Pearson W Jr, eds. Baltimore: Johns Hopkins University Press.

PCEMOE [Planning Commission for Expanding Minority Opportunities in Engineering]. 1974. Minorities in Engineering: A Blueprint for Action. New York: Alfred P. Sloan Foundation.

Saline LE. 1974. Guest editorial: A national effort to increase minority engineering graduates. IEEE Transactions on Education 17(1):1–2.

Weinberger CJ. 2018. Engineering educational opportunity: Impacts of 1970s and 1980s policies to increase the share of Black college graduates with major in engineering or computer science. In: U.S. Engineering in a Global Economy, 87–128. Freeman RB, Salzman H, eds. University of Chicago Press.

The minority engineering effort led to an increase in the representation of African Americans in engineering, but future progress depends on renewed efforts to welcome new cohorts of young engineers into the profession.

Does the Minority Engineering Effort Have a Flat Tire?

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College graduates who major in engineering consistently have strong earnings potential relative to college graduates with other majors (Andrews et al. 2022; Brown and Corcoran 1997; Daymont and Andrisani 1984; Grogger and Eide 1995; Polachek 1978; Weinberger 1998, 2018). The preceding article describes historical details and early achievements after a national organization of engineers formed in the early 1970s utilized a systems engineering approach to design and implement policies that would facilitate the participation of African American students in accredited engineering bachelor's degree programs (Pierre and Weinberger 2024). Despite the initial success of the minority engineering effort (MEE), with the annual number of African American engineering graduates rising from 400 in 1970 to 1,400 in 1980 and 3,000 in 1995, all indications are that this effort ran out of steam about 20 years ago. However, previous analysis of trends does not provide a complete picture. Here, I attempt to address some of the methodological issues and to provide accessible graphs that describe recent trends in different ways that complement existing analyses to provide a more complete picture of historical and emerging trends; all of these lead to similar conclusions. Pursuing a deeper understanding of the extent to which members of historically excluded groups are facing renewed barriers to entering engineering careers should be of concern to the profession.

It is always difficult to identify the permanence of a trend in progress. Statistics collected annually by the US Department of Education and published periodically by the American Society for Engineering Education[1] now describe a decade of unchanging representation of African American citizens, and the simultaneous doubling of the representation of Hispanic citizens, among new engineering graduates who were not designated foreign nationals. Using the same federal counts of degrees conferred spanning a longer interval (1981–2015), journalist Ashley Smart documented two decades of growth, then a monotonic decline in the representation of African American scientists and engineers among new college graduates between 2004 and 2011, followed by flatlining; this reporter linked the change to the dismantling of affirmative action programs that had been designed to facilitate the recruitment and retention of minority students (Smart 2020). In this article, I provide some historical context and describe different ways to think about what those statistics might mean because analyses based on samples of engineering graduates, or on samples of bachelor's degree graduates, conflate changes in the demographic composition of the birth cohort with changes in the propensity to attend college, major in engineering, and complete college among individual cohort members. A clearer picture of true trends emerges when the propensity to complete an engineering degree is computed for each complete birth cohort.

Pursuing a deeper understanding of the extent to which members of historically excluded groups are facing renewed barriers to entering engineering careers should be of concern to the profession.

To put these statistics into context, it is helpful to describe the timing of different stages of the MEE, explained in greater detail in the preceding article (Pierre and Weinberger 2024) and "Engineering Educational Opportunity: Impacts of 1970s and 1980s Policies to Increase the Share of Black College Graduates with Major in Engineering or Computer Science" (Weinberger 2018). During the 1960s, about 300 African American engineering students graduated per year, at least half of those from one of six historically Black campuses. The national effort to increase the number of African American engineers began in the early 1970s, with active participation by a handful of campuses representing about 20% of engineering graduates nationally, and the founding of both national and campus-specific programs dedicated to the success of minority engineering students with support from industry, the federal government, and the Sloan Foundation. A particular milestone of the early effort is the publication of *A Blueprint for Action* (PCEMOE 1974). This effort arose in response to Nixon administration affirmative action policies after GE and other employers realized it would be challenging, if not impossible, to hire significant numbers of African American engineers. In 1980, with the passage by Congress of the Science and Technology Equal Opportunities Act, the federal government committed to ensuring access to science and engineering education for all US residents and began to collect detailed statistics on the race, gender, and college major of all new graduates. The NAE-sponsored 1973 symposium that marked the beginning of the MEE focused on African American men, but the issue of broadening the effort to include other minorities began during that first gathering and continued at the first meeting of the new NAE Committee on Minorities in Engineering (Grosch 1974; NAE 1973). At that time, fewer than 1% of new engineering graduates were women nationwide, compared to 2.5% at the six HBCU engineering programs. As the MEE entered the 1980s, the inclusion of minority women became the norm. By the mid-1990s, 15% of new engineering graduates were women, but 30% of new African American engineering graduates were women nationwide, and, among African American HBCU engineering graduates, 40% were women (Weinberger 2018).

I'll begin by providing a longer view of changes between 1940 and 2022 in the demographic composition of US children, the educational attainment of their parents, the propensity to complete Algebra II before high school graduation, and the propensity for young adults to hold a college degree, followed by a careful analysis of the propensity for successive cohorts to hold a bachelor's degree in engineering.

The composition of the US-born-and-educated population has shifted over the years, though not as dramatically as the current public perception would suggest. Figure 1 depicts changes among children in the 1–10 age range since 1940. At the outset of the MEE, less than 15%

[1] See ira.asee.org/by-the-numbers/.

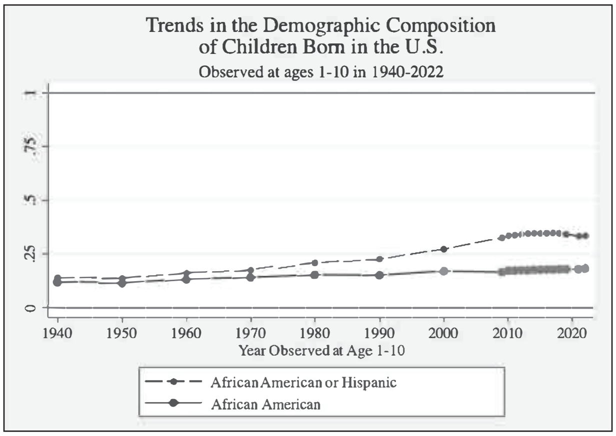

FIGURE 1 US Decennial Census 1940-2000, and American Community Survey 2009-2022, restricted to individuals age 1-10 who were born in the US, n=13.1 million. Point estimates are weighted means per year.

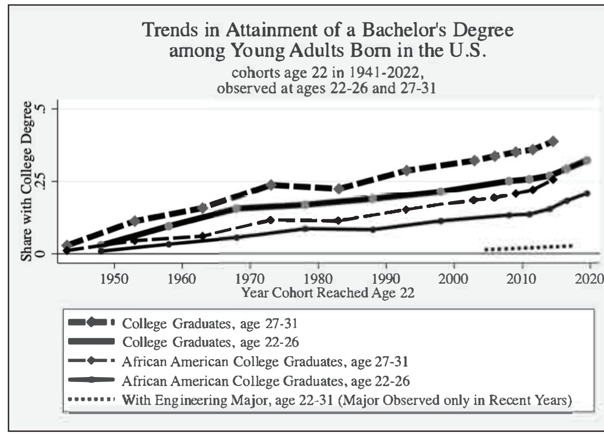

FIGURE 2 US Decennial Census 1950-2000, and American Community Survey 2009-2022 (excluding 2020), restricted to individuals age 22-31 who were born in the US (n=11.7 million). Engineering curve based on linear fit within 2009-2022 subsample (n=4.1 million). Other estimates are weighted means per decennial census year (1940-2000), or aggregated across 2-3 year intervals (2009-11, 2012-14, 2015-17, 2018-19, 2021-22).

of US children approaching college age were identified by their parents as Black or African American, and this share has grown no higher than 18%. Due to gradual immigration, the share of US-born children identified in the broad “Hispanic” category grew from less than 4% to just under 17% by 2010 and then flattened out over the past decade; a majority of these children resided with a parent who was also born in the US in nearly every decade since 1940 (with the single exception of 2000–2009). Because of the growth of this portion of the population, it is understandable that the number of Hispanic engineers has grown more quickly than the number of African American engineers. But this does not explain why both groups continue to be underrepresented in engineering.

Another shift in the background of new cohorts of children is a large increase in parents’ educational attainment. The share of US-born children (ages 1–10) residing with a college-educated parent grew from 13% in 1960 to 45% in 2022. Among African American children, the corresponding statistics are 3% in 1960, rising to 30% in 2022; for Hispanic children, 3% in 1960, rising to 22% in 2022. Over the same period, the propensity for high school graduates to complete a course in Algebra II nearly tripled, reaching 85% by 2019 and surpassing 80% for African American and Hispanic students; this is a dramatic change from the historic restriction of access to high school algebra to a select few (Jones and Coxford 1970; NCES 2021; Weinberger 2014). Shifts in relative numbers, parents’ educational attainment, and equity of access to high school mathematics preparation have all contributed to an increase in the representation of African American and Hispanic graduates within the college-educated workforce.

However, nearly universal enrollment in Algebra II does not mean that K–12 equity has been achieved. Nationwide, students from advantaged families are increasingly likely to complete a course in calculus before leaving high school, and to begin college with an apparent head start in securing scarce seats in competitive programs (Bressoud 2021). Here, a new racial gap has emerged. In 1982 only 5% of new high school graduates had taken a year of calculus.[2] By 2019 the share had grown to 15%, but to only 6% among African American students.[3]

Figure 2 describes the timing of increased educational opportunity within and between birth cohorts. The average propensity to hold a college degree is plotted against the average year in which a cohort reached age 22. For example, a cohort that was 22–26 in 1980 would have turned 22 in 1976–1980 and is plotted at 1978, and the cohort that was 27–31 in in 1980 is plotted five years earlier. The slopes describe how quickly access to college expanded over time, while the vertical distance between the younger and older observations represents the extent to which individuals continued to complete college degrees between the ages of 27 and 31. The growing distance between the younger and older observations of successive cohorts illustrates

[2] nces.ed.gov/programs/digest/d19/tables/dt19_225.30.asp, accessed 7/30/24

[3] nces.ed.gov/programs/digest/d22/tables/dt22_225.30.asp, accessed 7/30/24

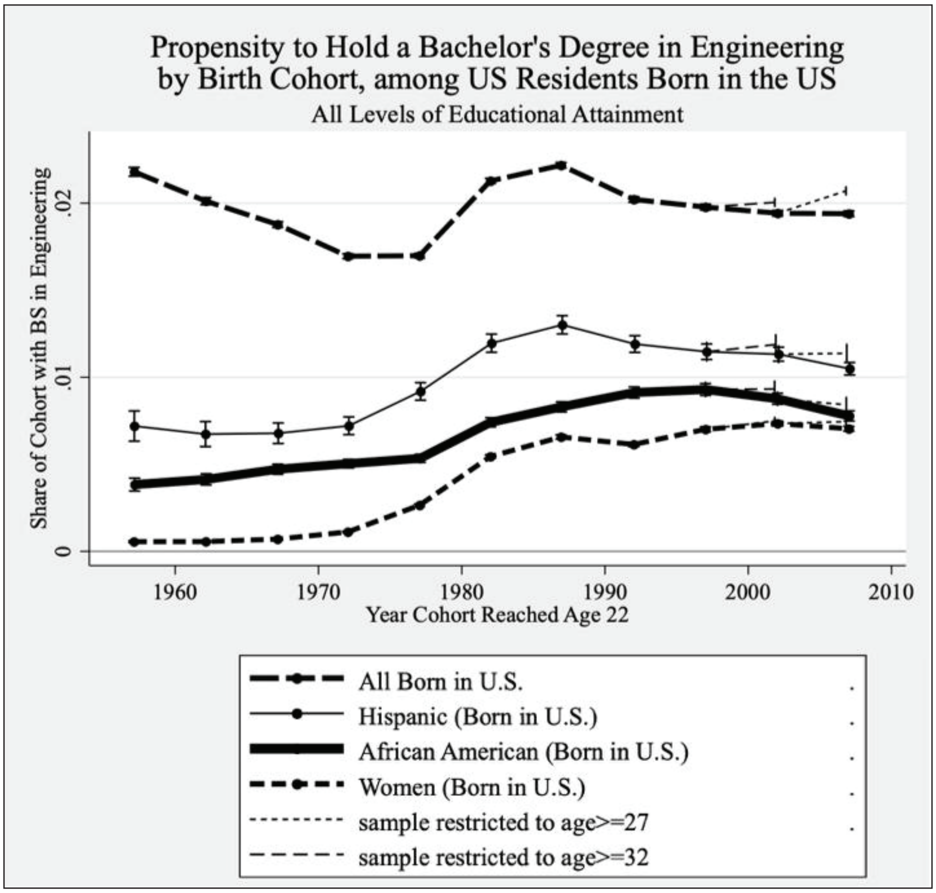

FIGURE 3 Current representative samples of US Residents, drawn from the American Community Survey 2009-2022 (excluding 2020), US Census Bureau, restricted to individuals between 22 and 89 years old and born in the US between 1933 and 1987, n=21.8 million. Error bars represent 90% confidence intervals (barely visible in most cases). Point estimates are aggregated across 5-year birth cohorts, age 22 in 1955-59 - 2005-09. (the 1955-59 cohort was age 72-76 in 2009, 85-89 in 2022; the 2005-09 cohort was age 22-26 in 2009, 35-39 in 2022). The two youngest cohorts include individuals under the age of 32 and estimates understate eventual attainment; for these two cohorts, alternate estimates omit observations younger than the youngest member of the preceding cohort.

that, over time, a growing share of eventual college graduates had not yet completed their degrees within the 22–26 age range. This means that measuring the college completion rate of a cohort requires careful thought about the age at which the measurement is taken. However, those who complete college later in life are less likely to major in engineering. When analyzing current trends, and especially when computing the ratio of engineering graduates to all new graduates, understanding changes in the demographic characteristics of successive waves of graduates requires information about the age distribution of those new graduates as well as their race or ethnicity.

The final curve plotted in the lower right-hand corner of figure 2 illustrates the tiny share of college graduates who are engineering majors. Large representative samples of the US population that include information about engineering college graduates of all ages were collected only twice before 2009. Fortunately, for each of the years from 2009–2022, the Census Bureau includes a question about college major in its annual American Community Survey of 1% of the US population; this includes millions of observations and hundreds of thousands of individuals with bachelor's degrees in engineering (Ruggles et al. 2024). For this reason, the following figures will use only the data from 2009–2022 (excluding error-prone data from pandemic year 2020). Despite its recent collection, the attainment of bachelor's degrees in engineering among both young and old individuals who were born (and predominantly educated) in the United States can be used to estimate the prevalence of engineering degree attainment among earlier cohorts using a retrospective approach that infers the educational opportunities available at a given point in time by looking at the educational attainment reported by those who were college age at that time. In figure 2, only the cohorts age 22–31 are depicted, but the remainder of the figures examine cohorts who reached age 22 in 1955–59, 1960–64, 1965–69, and so on. This approach provides a clear picture of the achievements that followed the organization of the MEE.

Three alternative ways to describe changes over time are presented in figures 3–5. Figure 3 begins with entire birth cohorts—every individual born in the United States in a particular five-year interval—rather than selecting only engineering graduates for analysis. This presentation provides the clearest picture of trends in opportunities to

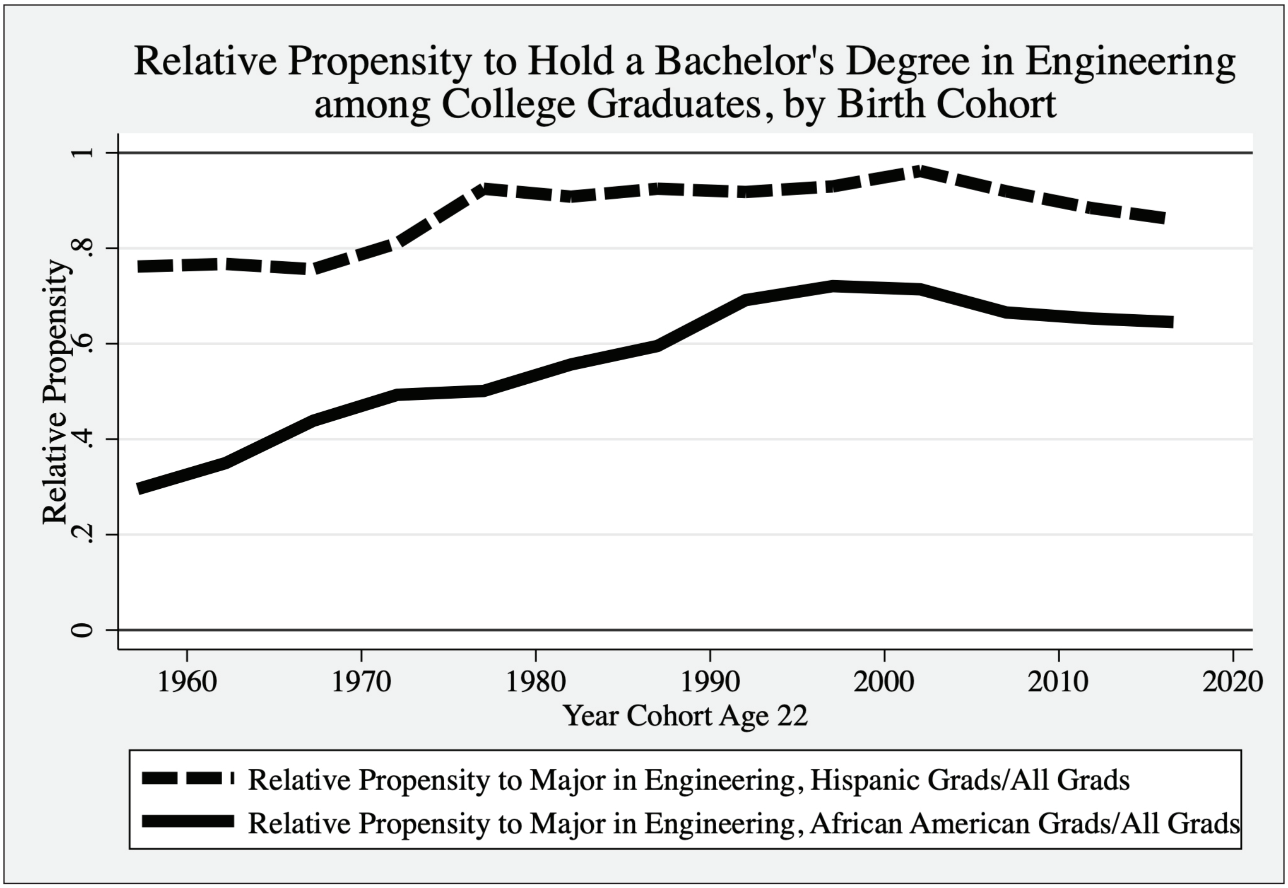

FIGURE 4 Current representative samples of US Residents, drawn from the American Community Surveys of 2009-22 (excluding 2020), US Census Bureau, restricted to individuals between 22 and 89 years old and born in the US between 1933 and 1997, n=7.7 million. Point estimates are aggregated across 5-year birth cohorts, age 22 in 1955-59 - 2015-19. (The oldest cohort was age 72-76 in 2009, 85-89 in 2022; the four youngest cohorts were: age 27-31 in 2009, 40-44 in 2022; age 22-26 in 2009, 35-39 in 2002; age 22 in 2010-2014, 30-34 in 2022; age 22 in 2015-2019, 25-29 in 2022). Relative propensity is the propensity among a subset of college graduates divided by the propensity among the full population of US college graduates of the same cohort.

study engineering for successive cohorts old enough to have completed their education. Figure 4 shows changes over time within the smaller population that completed a bachelor's degree. Figures 5a and 5b use the same samples as figures 3 and 4 to examine how trends in engineering participation compare with trends in computer science and various subsets of STEM fields.

Figure 3 describes trends in the propensity for members of successive cohorts to hold a bachelor's degree in engineering; the top curve is unconditional, and the remaining curves condition on demographic characteristics. As described in the preceding article (Pierre and Weinberger 2024), the MEE that began in the early 1970s led to an acceleration of the already slowly rising share of African American college graduates with engineering degrees. This presentation clarifies that the propensity of African Americans to become engineers increased throughout the 1960–1995 period, with a substantial increase in slope in the late 1970s that corresponds almost exactly with the cohort of students who enrolled in college the year the engineers of the MEE published the *Blueprint* report (and reached graduation age four or five years later). Previous research found that the magnitude and timing of growth in the number of new African American engineering graduates varied geographically, and were related to the educational infrastructure in place in the birth state as of 1965 (Weinberger 2018). It is notable that the corresponding curves for Hispanic and female members of the same cohorts show very different patterns of change; both of these groups have a steep upward slope between the early 1970s and the early 1980s in contrast with the later change among African

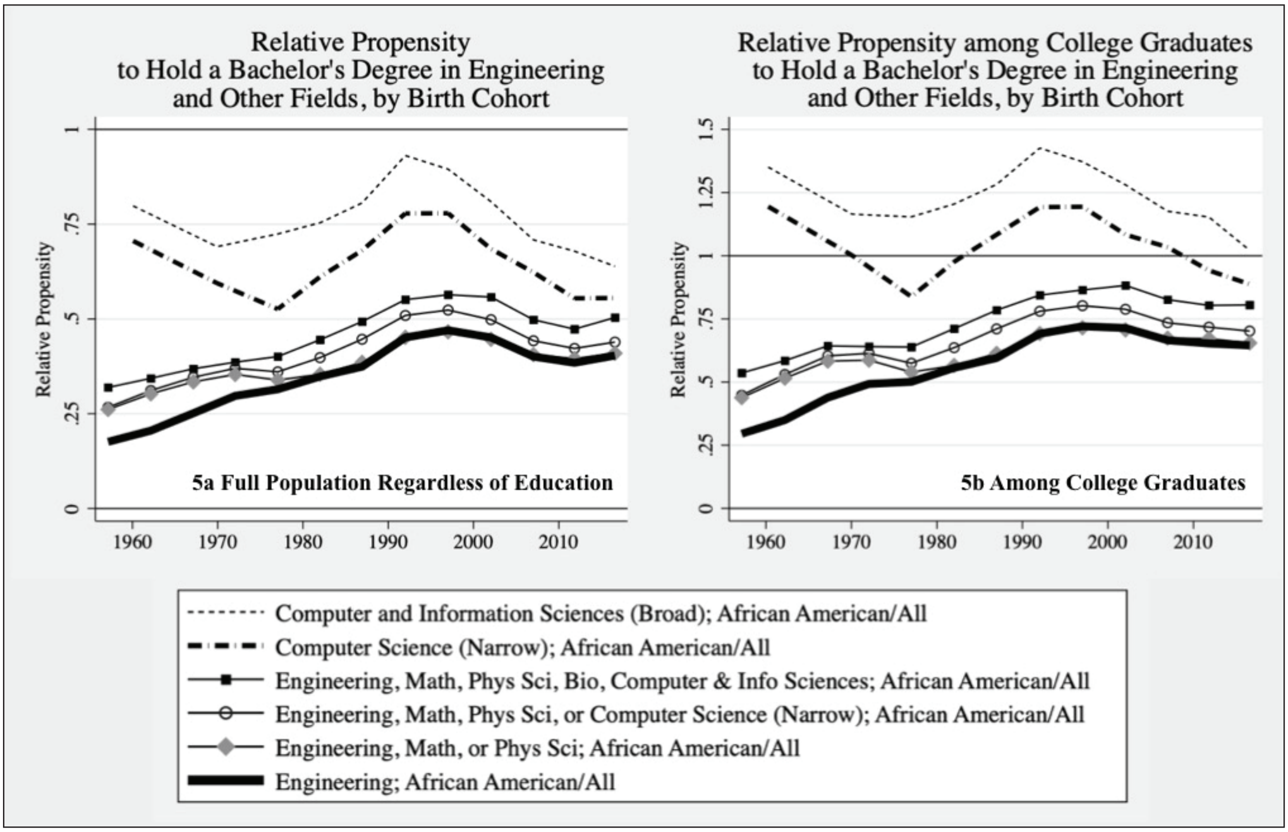

FIGURE 5a and 5b. FIGURE 5a: Same as figure 3 plus 2 additional young cohorts, n=24.2 million. Figure 5a relative propensity is the propensity among African American citizens divided by the propensity among the full US population of the same cohort. Figure 5b: Same as figure 4, n=7.7 million college graduates. FIGURE 5b relative propensity is the propensity among African American college graduates divided by the propensity among all US college graduates of the same cohort. Most point estimates are aggregated across 5-year birth cohorts, age 22 in 1955-59 - 2015-19. Between 1955 and 1974, computer science estimates are based on 10-year cohorts.

American engineers. The programs and policies developed during this time had a targeted impact on the number of African American engineers, both men and women, and appear to have addressed barriers specific to African American students. The results of these efforts complemented the effects of contemporaneous federal policies that applied to all women and minorities and of the contemporaneous Cold War expansion of engineering opportunities that applied to everyone.

Figure 3 also shows a decline in the share of the general population electing to study engineering throughout the 1990s and a slowing or stalled rate of growth among the African American population. While a decline appears to have affected the youngest cohorts, this is partially driven by the fact that some of the data come from younger individuals who have not yet completed their education. An additional set of estimates, indicated by dashed line segments, describe the means among cohort members who are at least as old as the youngest member of the preceding cohort; this set of less-negative or positive slopes underscores the role of age in producing the apparent decline. This blunt adjustment for differences in age suggests that the development of a statistical model that accounts for age at observation is needed to interpret the true trajectory of the propensity to study engineering. Additional analysis of the incomplete trajectories of the youngest sample members (not shown) suggests that the average propensity to attain an engineering degree is now on the rise for all groups, but that the rate of growth is similar among minority engineers, with *relative* participation rates that are no longer declining.

The analysis described in figure 3 is well suited for understanding impacts on educational opportunity because there is no reason to believe that the members of a particular birth cohort have different characteristics than observationally similar individuals born five years earlier or later. However, a limitation of this presentation of the data is that it is not clear to what extent the remaining differences between groups are due to differences in college-going vs. college major selection among enrolled students. To begin to address this issue, figure 4 provides answers to two questions: How does the share of college graduates who are engineering majors vary by race or ethnicity, and how does this change over successive birth cohorts? While figure 3 describes trends in the propensity of African Americans to hold a bachelor's degree in engineering (within the entire cohort, college-educated or not), figure 4 describes trends in *relative* propensities within the subset of the cohort that completed a bachelor's degree, where relative propensity is defined as the propensity of African American or Hispanic college graduates to hold an engineering degree divided by the propensity of all US college graduates in the same age range to hold an engineering degree. This presentation might be of less use to historians or economists interested in the net impacts of prior policy changes, but of more relevance to university administrators interested in understanding the extent to which remaining differentials are related to college access rather than opportunities to study engineering once enrolled. [4]

As in figure 3, the alternative measure depicted in figure 4 begins to slope downward near the turn of the century, and much more dramatically, but it is difficult to discern the extent to which this is due to changes in the number and composition of college graduates with other majors rather than a true decline. (Figure 5a will address this concern.) In any event, this presentation is closer to previous analyses that describe the racial composition of recent engineering graduates based on administrative counts of new degrees, and it is reassuring to find similar trends in retrospective data.

Figure 5 provides additional context by comparing the African American trends in engineering degree completion depicted in figures 3 (5a) and 4 (5b) with other college majors. While African American undergraduate students remained substantially underrepresented in engineering throughout the 50-year history of the MEE, they faced far less disparity in the emerging field of computer science and—among college graduates—surpassed national averages for a sustained period of time (Weinberger 2018). Additional curves included in these figures clarify that the gains in engineering participation throughout the 1970–1995 period led to net gains in the representation of African American graduates in science or engineering fields, and that the apparent flattening or decline after 1995 has been shared with other STEM fields.

Figures 5a and 5b also provide a side-by-side comparison of estimated trends in the relative propensity to complete an engineering degree both within the full population and within the subset of the population that holds a college degree. This presentation clarifies that the downturn that began near the turn of the century is robust, and not an artifact of changing characteristics of college graduates. However, among the youngest cohorts, restricting to college graduates leads to the appearance of continued decline, while the true trend in the full population seems to have flattened with an inkling of an upturn. Many members of these youngest cohorts have not yet completed their education, and only time will tell what will happen next.

The minority engineering effort has had lasting effects on the US workforce.

All three of these complementary approaches point to the conclusion that the MEE, and the federal and local policies that followed, successfully led to an increase in the share of African American citizens with bachelor's degrees in engineering that reached its peak near the turn of the century. Figure 3 indicates that the remarkable growth between 1975 and 1999 in the propensity of African American youth to become engineers has not continued and did not come close to attaining equality. The following figures confirm that relative propensities among younger cohorts also began to decline at that time and appear to be flattening out near the level previously observed in the late 1980s. Where we will go from here is a story yet to be determined.

What might be done to redirect the trend back onto an upward trajectory? Research into college major choices points toward social and psychological roadblocks facing even academically well-prepared students from underrepresented groups (Margolis and Fisher 2002; Seymour 1992; Seymour and Hewitt 1997; Seymour et al. 2019). The success of HBCU programs has been attributed to their historical mission to teach underserved students,

[4] For deans of engineering, and to provide a deeper understanding of differentials in access, it might be even more helpful to create a version of this figure specific to the subset of campuses containing an engineering program, but this analysis could not be completed within the time frame of the current publication.

beginning with emancipated slaves who had previously been forbidden to read, and to an academic environment that provides encouragement and an expectation of success (Nettles 1988; Slaughter 2009; Trent and Hill 1994). These programs continue to prepare a disproportionate share of African American engineers for successful and lucrative careers (Mountjoy and Hickman 2021; Weinberger 2018). Students in settings where their identity sets them apart often report a sense of isolation from their classmates (Bix 2013; Landis 1991, 2005; Weinberger 2018). This can be mitigated by creating a sense of community within a classroom, or via extracurricular support structures. In psychology, a controlled experiment that included a short (one-hour) intervention to foster a sense of belonging and understanding that adversity can be overcome with persistence was completed in the spring of freshman year at Stanford. This brief experience had large, cumulative impacts on the academic attainment of African American students over each of the following semesters, with longer-lasting impacts on health three years later and career satisfaction and success, psychological well-being, community involvement, and leadership 7–10 years later (Brady et al. 2020; Walton and Cohen 2011). This approach was moved into the classroom with a similar one-time intervention—that also incorporates the ideas of Brown (1997)—assigned to two of the five discussion sections led by each of three teaching assistants in a physics course for engineers. Exposure to the intervention both built "a community of learners" and improved academic outcomes and persistence in the major for everyone, with particularly large gains for underrepresented students (Binning et al. 2020). Whether or not the trend in relative rates of engineering participation reverses, ensuring that members of the profession feel capable and valued is a worthy goal in and of itself.

Students less well prepared for college coursework face additional bureaucratic barriers, even if they have the potential to attain a steep upward trajectory during their college years. Data-rich research into the economics of oversubscribed college majors in large public universities documents that students coming from under-resourced high schools suffer disproportionate losses in both opportunities to pursue their chosen academic trajectories and later earnings when freshman-year GPA is used to ration admission to a major (Bleemer and Mehta 2022). And a recent study compared thousands of students offered a one-time workshop and short-term mentoring to otherwise comparable students whose GPAs were barely too high to qualify for the program. This study provides large-scale causal evidence that a small amount of encouragement—supported by credible evidence that initial academic challenges can be overcome—can have persistent impacts on both academic and career trajectories over 7–10 years (Canaan et al. 2024). All of these studies point to solutions that can be implemented at the campus level.

The MEE has had lasting effects on the US workforce. Within the entire population of employed individuals holding a bachelor's degree in engineering (including many with higher degrees as well), 2009–2022 saw no change over time in the 70% share who either were born in the United States or arrived before age 17. Over the same decade, the representation of US-born-and-educated African American engineers increased by 30%, from 3.0-3.9% of all employed engineers (or, from 4.3-5.6% of employed engineers born in the United States). This growth reflects the groundwork laid by the early visionaries of the MEE, with their focus on African American representation in the engineering profession. However, the majority of the change observed over the past decade is driven by cohorts educated more than 20 years ago; without a renewed effort, the overall rate of increase—while still positive—can be expected to begin falling as those currently in their mid-40s reach retirement age, unless new cohorts of young engineers begin to narrow the gap in relative attainment rates once again.

References

Andrews RJ, Imberman SA, Lovenheim MF, Stange KM. 2022. The returns to college major choice: Average and distributional effects, career trajectories, and earnings variability, revised March 2024. NBER Working Paper #30331. Online at www.nber.org/papers/w30331.

Binning KR, Kaufmann N, McGreevy EM, Fotuhi O, Chen S, Marshman E, Kalender ZY, Limeri L, Betancur L, Singh C. 2020. Changing social contexts to foster equity in college science courses: An ecological-belonging intervention. Psychological Science 31(9):1059–70.

Bix A. 2013. Girls Coming to Tech!: A History of American Engineering Education for Women. Cambridge, Massachusetts: MIT Press.

Bleemer Z, Mehta A. 2022. Will studying economics make you rich? A regression discontinuity analysis of the returns to college major. American Economic Journal: Applied Economics 14(2): 1–22.

Brady ST, Cohen GL, Jarvis SN, Walton GM. 2020. A brief social-belonging intervention in college improves adult outcomes for Black Americans. Science Advances 6(18):eaay3689.

Bressoud DM. 2021. The strange role of calculus in the United States. ZDM 53(3):521–33. Online at https://doi.org/10.1007/s11858-020-01188-0

Brown C, Corcoran M. 1997. Sex-based differences in school content and the male-female wage gap. Journal of Labor Economics 15(3):431–65.

Canaan S, Fischer S, Pierre M, Schnorr G. 2024. Keep me in, coach: The short- and long-term effects of targeted academic coaching, working paper online at scanaan.github.io/papers/coaching_v9.pdf.

Daymont TN, Andrisani PJ. 1984. Job preferences, college major, and the gender gap in earnings. Journal of Human Resources 19(3):408–28.

Grogger J, Eide E. 1995. Changes in college skills and the rise in the college wage premium. Journal of Human Resources 30(2):280–310.

Jones P, Coxford AF Jr. 1970. Mathematics in the Evolving Schools. In: A History of Mathematics Education in the United States and Canada, thirty-second year book, 38. Reston, Virginia: National Council of Teachers of Mathematics.

Landis RB. 1991. Retention by design: Achieving excellence in minority engineering education. National Action Council for Minorities in Engineering.

Landis RB. 2005. Retention by Design, Achieving Excellence in Minority Engineering Education. College of Engineering, Computer Science and Technology, California State University, Los Angeles.

Margolis J, Fisher A. 2002. Unlocking the Clubhouse: Women in Computing. Cambridge, Massachusetts: MIT Press.

Mountjoy J, Hickman BR. 2021. The returns to college(s): Relative value-added and match effects in higher education. Becker Friedman Institute. NBER Working paper 29276.

Nettles M. 1988. Toward Black Undergraduate Student Equality in American Higher Education. Westport, Connecticut: Greenwood Press.

Pierre PA, Weinberger CJ. 2024. The 50-year history of the minority engineering effort: How the engineering profession sparked the movement to diversify its workforce. The Bridge 54(4):23-30.

PCEMOE [Planning Commission for Expanding Minority Opportunities in Engineering]. 1974. Minorities in Engineering: A Blueprint for Action. New York: Alfred P. Sloan Foundation.

Polachek SW. 1978. Sex differences in college major. ILR Review 31(4):498–508.

Ruggles S, Flood S, Sobek M, Backman D, Chen A, Cooper G, Richards S, Rodgers R, Schouweiler M. 2024. IPUMS USA: Version 15.0 [dataset]. Minneapolis, Minnesota: IPUMS. Online at https://doi.org/10.18128/D010.V15.0.

Seymour E. 1992. 'The problem iceberg' in science, mathematics, and engineering education: Student explanations for high attrition rates. Journal of College Science Teaching 21(4):230–38.

Seymour E, Hewitt NM. 1997. Talking about Leaving: Why Undergraduates Leave the Sciences. Boulder, Colorado: Westview Press.

Seymour E, Hunter A-B, Weston TJ. 2019. Why we are still talking about leaving. In: Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education, 1–53. Seymour E, Hunter A-B, eds. Springer.

Slaughter JB. 2009. African American males in engineering: Past, present and a future of opportunity. In: Black American Males in Higher Education: Research, Programs and Academe volume 7, 193–208. Frierson H, Wyche J, Pearson W, eds. Emerald Publishing Limited.

Smart A. 2020. After years of gains, Black STEM representation is falling. Why? Undark, Nov 11.

Trent W, Hill J. 1994. Contributions of historically Black colleges and universities to the production of African American scientists and engineers. In: Who will Do Science? Educating the Next Generation, 68–80. Pearson Jr. W, Fechter A, eds. Baltimore: Johns Hopkins University Press.

Walton GM, Cohen GL. 2011. A brief social-belonging intervention improves academic and health outcomes of minority students. Science 331(6023):1447–51.

Weinberger CJ. 1998. Race and gender wage gaps in the market for recent college graduates. Industrial Relations 37(1):67–84.

Weinberger CJ. 2014. Are there racial gaps in high school leadership opportunities? Do academics matter more? The Review of Black Political Economy 41(4):393–409.

Weinberger CJ. 2018. Engineering educational opportunity: Impacts of 1970s and 1980s policies to increase the share of Black college graduates with major in engineering or computer science. In: U.S. Engineering in a Global Economy, 87–128. Freeman R, Salzman H, eds. The University of Chicago Press. Online at www.nber.org/papers/w23703.

In the wake of the 2023 Supreme Court decision striking down the use of affirmative action in college admissions, engineering programs and employers retain a range of tools to expand opportunities for underrepresented groups to enter the field.

Many Mountains to Climb:

The Enduring Imperative to Expand Access to Engineering


Kesha Moore


Amalea Smirniotopoulos

Kesha Moore and
Amalea Smirniotopoulos

Our nation confronts a growing array of complex scientific and technological challenges, from combatting climate change to managing the risks of artificial intelligence. Our ability to solve these problems relies on our capacity to think critically and innovate. To succeed, we cannot leave talent on the table. Diverse representation in the fields of science and technology can expand the types of scientific questions asked, foster innovations, and help mitigate the impact of human biases on scientific knowledge (Herring 2009; Holstein 2009; Hunt et al. 2015; UCMP nd.; Minkin 2023; Rock & Grant 2016).

Unfortunately, while talent is everywhere, opportunity is not. Gifted Black, Latinx, and Indigenous people have historically been underrepresented in scientific, technology, and medical (STEM) fields and continue to face unfair barriers that prevent them from entering and advancing in careers like engineering. These underrepresented racial and ethnic groups lack access to preparatory courses, confront hostile learning environments, and struggle in the absence of mentorship, funding, and research opportunities. The need to eliminate barriers to opportunity becomes even more urgent as our nation becomes increasingly diverse (Frey 2020). We cannot risk losing out on the ben-

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efits of the talents and skills of another generation.

Engineering programs and firms have a moral, legal, and economic imperative to ensure that the profession is equally accessible to all. Targeted pipeline programs and other practices can increase the success of underrepresented racial and ethnic groups in engineering and other STEM fields. While opponents of civil rights have attacked programs aimed at redressing discrimination and increasing diversity, equity, inclusion, and accessibility (DEIA), these programs remain lawful and necessary. Engineering leaders should replicate successful pipeline programs like the NACME Scholarship Program and the Louis Stokes Alliance for Minority Participation Program, which have helped break down the barriers that underrepresented students face.

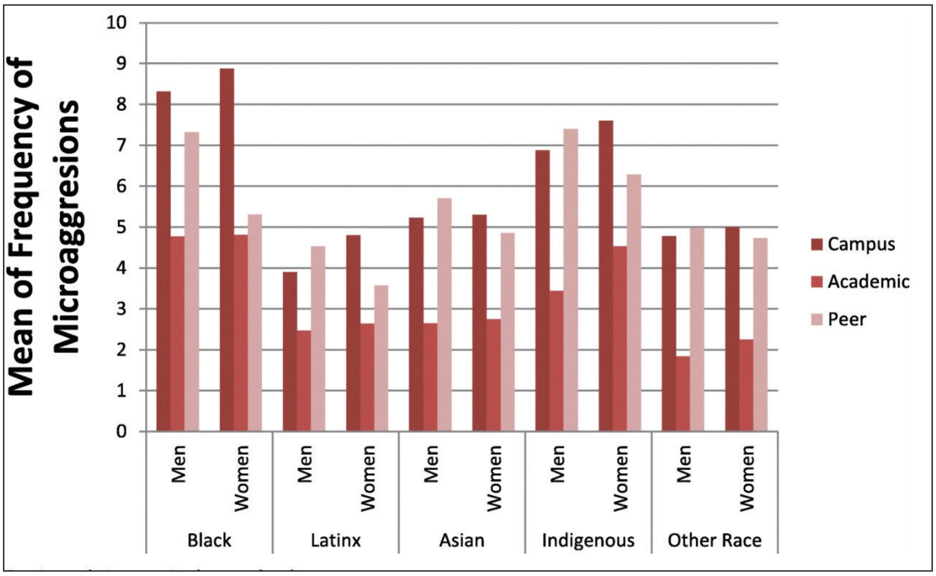

FIGURE 1 Mean frequency of microaggressions among STEM students by race and gender. Source: Lee et al. 2020.

Black People and Underrepresented Groups Encounter Unfair Barriers that Prevent Them from Becoming Engineers

Despite the progress that we have made in expanding access to engineering and other STEM professions, Black, Latinx, and Indigenous workers continue to be underrepresented in the STEM workforce (NCSES 2023). In 2021, Latinx workers comprised 15%, Black workers 9%, and Indigenous workers less than 1% of the STEM workforce. Engineering has the least racially and ethnically diverse workforce, with underrepresented racial groups comprising less than 3% of the engineering workforce (NCSES 2023). Moreover, those few Black, Latinx, and Indigenous STEM workers earn less than their white or Asian American peers (Fry et al. 2021). This underrepresentation is the result of discriminatory barriers that make it harder for Black, Latinx, and Indigenous people to enter and thrive in these professions.

Because jobs in engineering and other STEM fields rely more heavily on specialized bachelor's and graduate-level degrees (Fry et al. 2021), they are harder for underrepresented groups to access. Even before being able to attend college and major in STEM fields, many Black and Latinx students cannot access the types of coursework needed to prepare them for STEM careers. A US Department of Education report (DOEd 2023) analyzing 2020-2021 data reveals substantial racial and ethnic disparities in access to science and math coursework across public high schools in the United States. Public high schools with high enrollments of Black and Latinx students were less likely to offer calculus (35% vs. 54%) and computer science (40% vs. 54%) than high schools with low enrollments of Black and Latinx students.

Moreover, while numerous studies have documented the importance for students to find a community and develop a positive identity in order to succeed academically (Brooms & Davis 2017; Holmes et al. 2000; Strayhorn 2008), Black students face repeated microaggressions in higher education that undermine their mental health, academic performance, and ability to complete their degree in a STEM field (McGee 2020; True-Funk et al. 2021). Empirical studies of students of color with STEM majors reveal that various combinations of underrepresented racial and gender identities are associated with distinct experiences of reduced self-efficacy and self-esteem, otherness, social isolation, and fear of conforming to stereotypes (Bottia et al. 2021; True-Funk et al. 2021). In a survey of 1,688 STEM majors at a large public university, researchers found that students of color experience racial microaggressions at academic, peer, and campus levels (Lee et al. 2020). As figure 1 shows, among STEM majors, Black students experienced the highest frequency of racial microaggressions in the sample (Lee et al. 2020).

Experiences with racism drive disparities in the completion of STEM degrees. Beasley and Fischer's (2012) longitudinal analysis revealed that experiences of racism are associated with increases in attrition among underrepresented students majoring in STEM and health sciences. Even students from underrepresented racial and ethnic groups with high grades report questioning their ability and value in STEM as a result of their experiences with racism (McGee and Bentley 2016). Social isolation similarly impacts the well-being and retention of these students (Lane 2017; Thacker et al. 2022; White and Fulton 2015). Underrepresented students report significantly higher levels of social isolation and psychological distress resulting from being in such small numbers in their courses and programs (White and Fulton 2015).

The lack of faculty diversity compounds the racial isolation of Black, Latinx, and Indigenous students. While faculty diversity is positively correlated with completion rates for students from underrepresented populations (Stout et al. 2018), many engineering and other STEM departments do not have diverse faculty. In 2019, only 10.1% of STEM faculty at four-year institutions are from underrepresented racial backgrounds (Bennet et al. 2020).

Engineering programs and firms should not be deterred from investing in programs that ensure that all talented individuals can thrive in the field.

The success of minority serving institutions (MSIs) in producing racially and ethnically diverse STEM graduates makes visible the steps that can be taken to reduce unfair barriers that prevent a more diverse pool of talented students from entering the STEM profession. Because they have a more welcoming climate and more diverse faculty, MSIs make an outsized contribution to the number of Black, Latinx, and Indigenous scientists (NASEM 2019). Thirty-one percent of Black students who earned a STEM PhD between 2010 and 2020 attended a historically Black college and university (HBCU) at some point in their education (Valez and Heuer 2023). Approximately 41% of Latinx students earning a STEM PhD between 2010 and 2020 attended a Hispanic-serving institution at some point in their education (Valez and Heuer 2023). A national survey of tribal colleges and universities (TCUs) found that over 20% of alumni of TCUs are working in STEM fields, and 53% of TCU graduates identified strong mentorship at the institution, as compared to 28% of alumni nationally (Boyer 1997).

Enduring institutional barriers continue to artificially limit the participation of Black, Latinx, and Indigenous people in STEM fields. The institutional difficulties in retaining and graduating talented Black, Latinx, and Indigenous students create additional challenges for engineering and STEM employers looking to diversify their workforce. This phenomenon is often called the "leaky pipeline" (Sarraju and Rodriguez 2023). While the percentage of Black, Latinx, and Indigenous people earning STEM undergraduate and graduate degrees has increased in recent years, these groups remain underrepresented among STEM graduates. Although Black individuals comprise 14% of Americans ages 18-34, they are only 9% of bachelor's, 11% of master's, and 7% of PhD degrees earned in STEM fields (NCSES 2023). Latinx individuals comprise 22% of the 18–34-year-old population, but only 17% of bachelor's, 13% of master's, and 9% of doctoral degrees earned in STEM fields (NCSES 2023). Indigenous people represent 0.9% of the US population ages 18-34, with less than half (0.4%) earning undergraduate or graduate degrees in STEM fields (NCSES 2023).

Pipeline Programs Can Help Break Down Barriers for Black Engineers

The barriers to the successful recruitment, retention, graduation, and employment of underrepresented racial groups in STEM professions can be mitigated by intentional, robust interventions throughout the pipeline. The National Academies of Sciences, Engineering, and Medicine identify a range of STEM intervention programs (SIPs), including internships, summer bridge programs, student professional groups, peer tutoring, "living and learning environments," and comprehensive interventions (NASEM 2016). The success of SIPs lies in their ability to not only enhance the knowledge and technical skills of underrepresented students, but also to make STEM environments more welcoming and inclusive, especially for women and underrepresented racial and ethnic groups. SIPs that promote positive social interaction and belonging among underrepresented students through cohort admissions, peer interactions, and intentional mentoring have been shown to improve participant outcomes (Matthews et al. 2021).

While mentorship and research experience are the most common types of SIPs offered in higher education, the most successful programs provide comprehensive support by implementing multiple interventions (Palid et al. 2023; Tsui 2007). Tsui's (2007) review of literature identifies 10 distinct categories of intervention: summer bridge, mentoring, research experience, tutoring, career counseling and awareness, learning centers, workshops and seminars, academic advising, financial support, and curriculum and instructional reform. In a more recent analysis, Palid and colleagues (2023) identified six key features of SIPs (supplemental learning, mentorship, skill building, financial aid, socializing, and bridge programs), and all were associated with positive outcomes for participants. Both Tsui (2007) and Palid and colleagues (2023) argue that comprehensive SIPs provide the most successful outcomes for program participants because such programs engage the multiple institutional failures driving underrepresentation in STEM fields.

Intentional and sustained efforts can remove the barriers faced by aspiring scientists from underrepresented minority communities. Numerous programs attempt to expand the STEM educational pipeline for underrepresented racial groups before college, including the National Action Council for Minorities in Engineering (NACME) Scholarship Program. The NACME Scholarship Program is an intensive high school-through-university program. The program's mission is to assist promising Black, Latinx, and Indigenous students in overcoming barriers they may face when seeking to pursue STEM in higher education, but the opportunity is open to all students who meet its citizenship, GPA, major, and enrollment requirements. In a 2008 evaluation of the NACME Scholars program, NACME's partner universities graduated nearly one-third of all URM students receiving a BA in engineering in the 2007-2008 academic year (NACME 2008). Theis cohort of NACME Scholars maintained a 3.3 GPA on a 4.0 scale and 73% of them identified their NACME scholarship as a "very important" source of their academic funding (NACME 2008).

One successful pipeline program addressing barriers to bachelor's and graduate STEM degrees is the Louis Stokes Alliance for Minority Participation (LSAMP) Program. The LSAMP Program is an alliance program created by the National Science Foundation (NSF) in which NSF partners with higher education institutions to diversify the STEM workforce by fostering the success of historically and currently underrepresented Black, Latinx, Indigenous, and Pacific Islander students in STEM fields (NSF 2024). LSAMP combines a student academic and social integration framework with empirical studies of effective student retention interventions to design a comprehensive program aimed at guiding and supporting underrepresented students successfully through socialization with professional scientists (Clewell et al. 2006). LSAMP activities include interventions targeted at the student, faculty, and institutional/department levels, such as: summer bridge programs, scholarship/stipends, peer study groups, skills building seminars, learning centers, academic advising, summer academic enrichment, tutoring, research experience, mentorships, conferences, internships, career awareness, GRE test prep, graduate school admission support, graduate summer bridge, faculty workshops on teaching, diversity sensitivity training for faculty, faculty research program, new course development resources, curriculum material sharing, distance learning courses, and changes in institutional/departmental policies.

In an evaluation by the Urban Institute (Clewell et al. 2006) comparing LSAMP program participants to a national sample of non-participating underrepresented students and non-underrepresented students, findings revealed significant success in improving the academic success, retention, and graduation rates of program participants at both the undergraduate and graduate levels. At the undergraduate level, LSAMP participants earned on average higher GPAs than comparable non-participating students (Clewell et al. 2006). As figure 2 shows, LSAMP participants were also more likely to take additional coursework after their bachelor's degree than non-participating underrepresented racial groups, and more likely to pursue and complete a graduate degree in STEM than their non-participating underrepresented and non-underrepresented peers (Clewell et al. 2006).

Although the percentage of LSAMP participants working in STEM-related jobs was lower than non-underrepresented and comparable to national underrepresented rates, LSAMP participants were less likely than both comparison groups to report that their job was not related to their education (Clewell et al. 2006). Many of the non-STEM jobs among LSAMP participants were in related fields of health sciences and education; there is no meaningful difference in employment rates in STEM

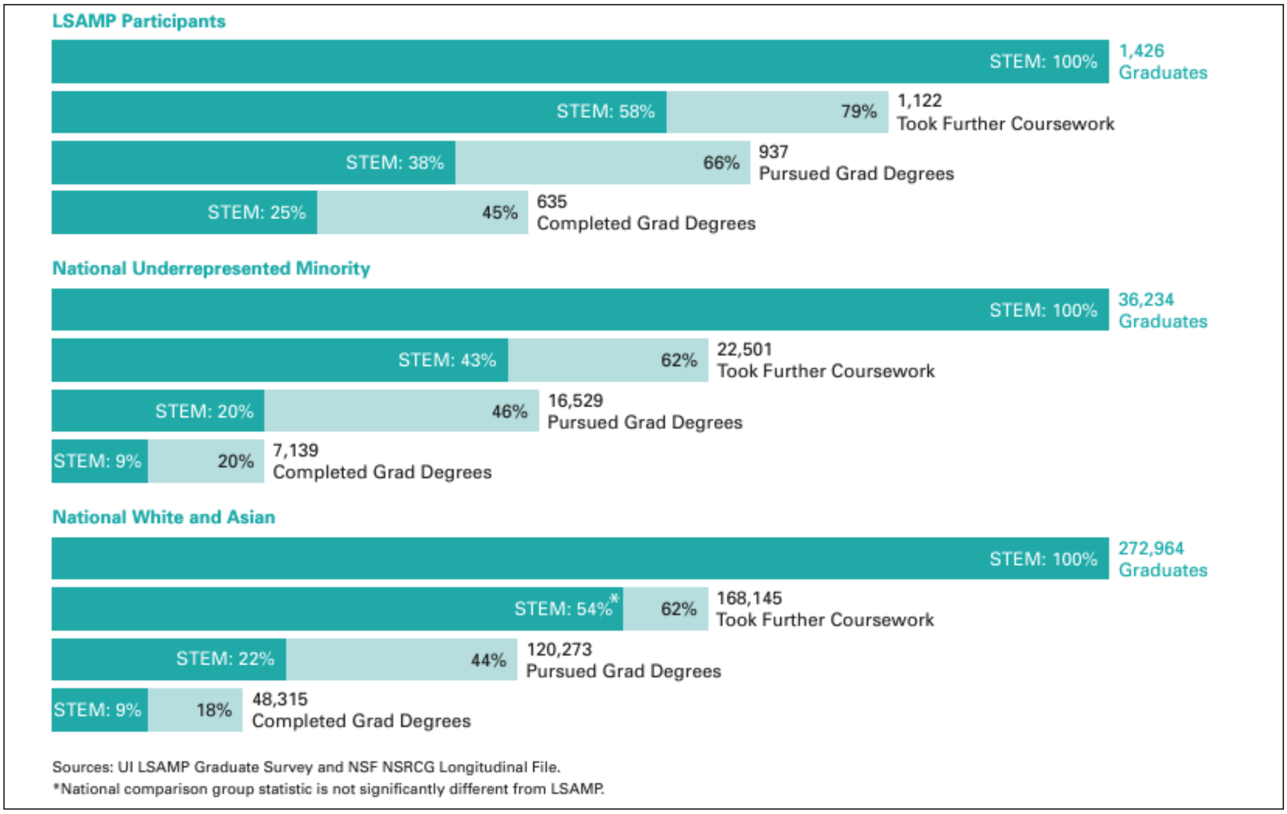

FIGURE 2 Graduate coursework, degrees pursued, and degrees completed among LSAMP and non-LSAMP participants.

and medicine for LSAMP participants and non-underrepresented groups (Clewell et al. 2006). In addition, the percentage of LSAMP participants who completed a PhD (9%) was comparable to the rate of non-underrepresented students and nine times greater than the national rate of underrepresented students' PhD completion (1%) (Clewell et al. 2006).

The LSAMP program also shows positive benefits for the participating institutions (Clewell et al. 2006). These institutions were better at retaining STEM students, expanding the diversity and inclusiveness of institutional culture, and creating better policies and practices to support students (Clewell et al. 2006).

Programs such as the NACME Scholarship Program and LSAMP demonstrate that STEM programs can successfully attract and graduate a more diverse STEM workforce. It is imperative that such programs continue and that other educational institutions build upon their success by adopting the practices shown to be effective.

Programs Aimed at Increasing Opportunities for Black People and Other People of Color to Enter the Engineering Profession Are Lawful

Engineering programs and firms can and should continue to invest in policies and practices that open up opportunities for Black, Latinx, and Indigenous people to join the profession. Programs that build robust pipelines, equalize opportunities, and address racial discrimination are generally lawful and can help higher education institutions and employers comply with their civil rights obligations. Importantly, the US Supreme Court's decision in *Students for Fair Admissions v. President & Fellows of Harvard College and Students for Fair Admissions v. University of North Carolina* (SFFA), 600 US 181 (2023), only governs the use of race as a tip in higher education admissions; it does not pertain to other programs aimed at increasing educational or employment opportunities or creating inclusive and welcoming environments. Engineering programs and firms should not be deterred from investing in programs that ensure that all talented individuals can thrive in the field.

Programs that break down barriers that prevent Black people from entering the engineering profession are consistent with federal civil rights laws. As the Eighth Circuit observed, "An inclusive recruitment effort enables employers to generate the largest pool of qualified applicants and helps to ensure that minorities and women are not discriminatorily excluded from employment. This not only allows employers to obtain the best possible employees, but it is an excellent way to avoid lawsuits." *Duffy v. Wolle*, 123 F.3d 1026, 1038–39 (8th Cir. 1997), abrogated on other grounds by *Torgerson v. Rochester*, 643 F.3d 1031 (8th Cir. 2011). As described in more detail in our reports (LDF 2023; LDF 2024), existing laws bar higher education institutions and employers from discriminating based on race. These laws include the Equal Protection Clause of the Fourteenth Amendments to the US Constitution, which prohibits intentional discrimination based on race by state and local governments; Title VI of the Civil Rights Act of 1964, which prohibits discrimination based on race, color, or national origin in the programs or activities of federal funding recipients, including colleges and universities, 42 U.S.C. §§ 2000d et seq.; Title VII of the Civil Rights Act of 1964, which prohibits employers from making decisions based on race or other characteristics when hiring and firing, making promotions and demotions, determining compensation and access to benefits, and setting the terms and conditions of employment, except in limited circumstances to redress past discrimination, 42 U.S.C. §§ 2000e et seq., 29 CFR § 1608.1(c); and Section 1981, which was passed as part of the Civil Rights Act of 1866 and prohibits private sector discrimination on the basis of race, color, and ethnicity when making and enforcing contracts, including employment contracts, 42 U.S.C. § 1981. Significantly, Title VI and Title VII prohibit both disparate treatment (i.e., explicitly treating employees differently based on a protected characteristic) and disparate impact (i.e., policies or practices that appear neutral but result in an unjustifiable discriminatory effect), though disparate impact violations under Title VI are only enforceable by government actors and not by private actors. As such, covered institutions may not adopt policies or practices that disproportionately exclude people based on race unless that policy serves a legitimate purpose and there are no less discriminatory alternatives available.

As recent guidance from the US Department of Education (2023) explains, "[A]ctivities intended to further objectives such as diversity, equity, accessibility, and inclusion are not generally or categorically prohibited under Title VI," including DEIA training; instruction in or training on the impact of racism; cultural competency or other nondiscrimination trainings; or efforts to assess or improve school climate. Similarly, as discussed in more detail in LDF's 2024 report, several courts have found that many programs focused on increasing employment opportunities are consistent with Title VII because they typically do not involve using race or other protected characteristics as a criterion in employment decisions (LDF 2024). For example, the US Equal Employment Opportunity Commission (EEOC) has stated that an employer may "adopt strategies to expand the applicant pool of qualified [Black] applicants, such as recruiting at schools with high Black enrollment," without making hiring decisions based on race (EEOC 2006). As a result, many pipeline programs are consistent with the scientific community's goal of developing the best talent and civil rights regulations that require fairness and equal opportunity.

Importantly, many DEIA programs actually help institutions comply with these antidiscrimination laws by breaking down unfair barriers that impede student success and block equal employment opportunities. DEIA initiatives thus help higher educational institutions comply with federal anti-discrimination laws by addressing harassing conduct, remedying prior racial discrimination, and fostering "a more positive and inclusive school climate" (DOEd 2023).

The Supreme Court's SFFA decision did not change the imperative for higher education institutions and employers to break down barriers to opportunity. In June 2023, the US Supreme Court ruled that the University of North Carolina's admissions policies violated the Fourteenth Amendment's Equal Protection Clause. 600 U.S. 181 (2023). The Court noted that an act that would violate the Equal Protection Clause also violates Title VI, which covers Harvard as a federally funded institution. *SFFA*, 600 U.S. at 198 n.2 (quoting *Gratz v. Bollinger*, 539 U.S. 244, 276, n.23 [2003]). The Court reasoned that those universities' consideration of an individual student's race failed to pass constitutional muster under the legal standard known as "strict scrutiny," as it was not narrowly tailored to meet a compelling government interest. *Id.* at 213. However, the Court ruled that nothing in its opinion should be construed to prohibit universities from considering an applicant's discussion of how race affected their life, whether through discrimination, inspiration, or otherwise. *Id.* at 230. Moreover, the Court recognized that race can be a factor in actions where the goal is "remediating specific, identified instances of past discrimination that violated the Constitution or a statute." *Id.* at 207. Finally, the decision did not limit the ability of public or private actors to increase diversity through policies and practices that do not include race as a criterion when making decisions.[1]

In order to advance scientific inquiry and address the pressing challenges we confront as a nation, we must do more to ensure that engineering and other STEM professions are open to talented Black, Latinx, and Indigenous people.

Since the SFFA decision, both courts and federal officials have reaffirmed the legality of programs that increase DEIA. As US Equal Employment Opportunity Commission Chair Charlotte A. Burrows confirmed, "It remains lawful . . . to ensure that workers of all backgrounds are afforded equal opportunity in the workplace" (Burrows 2023). Other commissioners have similarly reaffirmed that these programs are legal (Samuel and Shirazi 2023; Setty 2023). Many of the challenges, both pre- and post-SFFA, to policies designed to promote equal opportunity have not survived judicial scrutiny at the early stages of the litigation because the plaintiffs could not show that they were harmed by the policies at issue and therefore lacked standing to sue. *Do No Harm v. Pfizer Inc.*, 96 F.4th 106 (2d Cir. 2024) (challenging a fellowship program designed to increase the pipeline for underrepresented students); *Young v. Colorado Department of Corrections*, 94 F.4th 1242 (10th Cir. 2024) (challenging an anti-bias training program); *Lowery v. Tex. A&M Univ.*, 4:22-cv-03091, 2023 WL 6445788 (S.D. Tex. Sept. 29, 2023) (challenging alleged discrimination in hiring). We expect many future cases to face similar obstacles. Moreover, opponents of civil rights must affirmatively litigate to change existing law, and it will likely take years for successful challenges to progress through the courts to alter the law—if they prevail at all.

Engineering programs and employers thus retain a range of tools to expand opportunities for underrepresented groups to enter the field. First, they can adopt programs that do not consider race but address known barriers that unfairly disadvantage Black, Latinx, and Indigenous students and workers, such as offering implicit bias trainings, increased access to financial aid, and preparatory courses for all students who did not have access to prerequisites in their high schools. This category also includes scholarships, affinity groups, and mentorship programs that address the needs of particular racial groups but are open to all (DOJ & DOEd 2023). Second, they can adopt programs targeted at particular racial groups but where race is not used to determine access to limited opportunities, such as targeted recruiting programs designed to increase the number of underrepresented individuals in the applicant pool (EEOC 2006). Finally, they can adopt programs where race is used as a criterion in making critical decisions, such as access to scholarships and fellowships where the pool of funding is limited, in certain circumstances to remedy specific acts of past discrimination. These programs must be carefully constructed and supported by facts and data, as they may receive additional scrutiny. While the law governing many of these programs has not changed after SFFA, organizations must ensure that all policies comply with existing constitutional and statutory antidiscrimination requirements.

The preceding discussion focuses on federal law. Some states or localities have civil rights laws that are more robust than their federal counterparts—for example, protecting additional groups from discrimination (Cal. Gov. Code §§12900–12996). Unfortunately, other states have passed laws that prohibit actions that are lawful elsewhere. For example, Florida recently passed a law that prohibits all employers from requiring DEIA trainings or other activities that espouse particular views (Fla. Stat. § 760.10) and prohibits universities from spending funds on programs advocating for diversity, equity, and inclusion (Fla. Stat. § 1004.06). Some of these laws have been

[1] In SFFA, Justice Brett M. Kavanaugh made explicit in his concurrence that "governments and universities still 'can, of course, act to undo the effects of past discrimination in many permissible ways that do not involve classification by race.'" Students for Fair Admissions, Inc., 600 U.S. at 317. Justice Clarence Thomas also acknowledged the use of race-neutral policies in his concurrence, stating that "[r]ace-neutral policies may thus achieve the same benefits of racial harmony and equality." Id. at 284.

successfully challenged under the US Constitution or other legal theories (*Honeyfund.Com Inc, et al. v. Governor, State of Florida, et al.,* No. 22-13135 (11th Cir. Mar. 4, 2024)). These state laws also do not obviate the obligation under federal civil rights laws to ensure equal educational and employment opportunities through other lawful means. Institutions should consult all relevant state and local laws with the assistance of counsel but should not back down from their legal and moral duty to break down barriers to opportunity, especially for those individuals who come from marginalized and underrepresented communities.

Conclusion

In order to advance scientific inquiry and address the pressing challenges we confront as a nation, we must do more to ensure that engineering and other STEM professions are open to talented Black, Latinx, and Indigenous people. Engineering schools and employers must continue to invest in proven tools to break down barriers that bar these students and workers, such as pipeline programs. These programs are and remain lawful pathways to attain what we have never fully achieved: a multiracial democracy in which power is shared, dignity is sacred, and thriving is the standard.

References

Beasley MA, Fischer MJ. 2012. Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. Social Psychology of Education 15:427–48.

Bennet JC, Lattuca L, Redd K, York T. 2020. Strengthening pathways to faculty careers in STEM: Recommendations for systemic change to support underrepresented groups. Washington, DC: Association of Public and Land-grant Universities.

Bottia MC, Mickelson RA, Jamil C., Moniz K, Barry L. 2021. Factors Associated with College STEM Participation of Racially Minoritized Students: A Synthesis of Research. Review of Educational Research 91(4):614–48.

Boyer P. 1997. First survey of tribal college students reveals attitudes. Tribal College Journal 11(2):36–41.

Brooms DR, Davis AR. 2017. Staying focused on the goal: Peer bonding and faculty mentors supporting Black males' persistence in college. Journal of Black Studies 48(3):305–26.

Burrows CA.2023. Statement from EEOC Chair Charlotte A. Burrows on Supreme Court Ruling on College Affirmative Action Programs. Online at www.eeoc.gov/newsroom/statement-eeoc-chair-charlotte-burrows-supreme-court-ruling-college-affirmative-action.

Clewell BC, de Cohen CC, Tsui L, Deterding N. 2006. Revitalizing the Nation's Talent Pool in STEM. Washington, DC: The Urban Institute.

DOEd [US Department of Education]. 2023. Fact Sheet: Diversity & Inclusion Activities Under Title VI. Office of Civil Rights, Jan 31.

DOJ & DOEd [US Department of Justice & US Department of Education]. 2023. Questions and Answers Regarding the Supreme Court's Decision in Students for Fair Admissions, Inc. v. Harvard College and University of North Carolina, Aug 14.

EEOC [US Equal Employment Opportunity Commission]. 2006. Section 15 Race and Color Discrimination. Online at www.eeoc.gov/laws/guidance/section-15-race-and-color-discrimination.

Frey WH. 2020. The nation is diversifying even faster than predicted, according to new census data. Brookings Institute, July 1.

Fry R, Kennedy B, Funk K. 2021. STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity. Washington, DC: PEW Research Center.

Herring C. 2009. Does diversity pay?: Race, gender, and the business case for diversity. American Sociological Review 74(2):208–224.

Holmes SL, Ebbers L, Robinson DC, Mugenda A. 2000. Validating African American students at predominantly white institutions. Journal of College Student Retention: Research, Theory & Practice 2(1):41–58.

Holstein WJ. 2009. Diversity is even more important in hard times. New York Times, Feb 13.

Hunt DV, Layton D, Prince S. 2015. Why diversity matters. Washington, DC: McKinsey & Co.

Lane TB. 2017. Beyond academic and social integration: Understanding the impact of STEM enrichment program on the retention and degree attainment of underrepresented students. CBE-Life Sciences Education 15(3):1–13.

Lee MJ, Collins JD, Harwood SA, Mendenhall R, Huntt MB. 2020. "If you aren't White, Asian or Indian, you aren't an engineer": Racial microaggressions in STEM education. International Journal of STEM Education 7: article no. 48.

Matthews AK, Allen-Meares P, Watson K, Crooks N., Smith A., Hart A., Estrella M., Kim S. 2021. The use of strategies from the social sciences to inform pipeline development programs for under-represented minority faculty and students in the health sciences. *Journal of Clinical and Translational Science*. 2021;5(1):e73.

McGee EO. 2020. Interrogating structural racism in STEM higher education. Educational Researcher 49(9):633–44.

McGee E, Bentley L. 2016. The equity ethic: Black and Latinx college students reengineering their STEM careers toward justice. American Journal of Education 124(1):1–36.

Minkin R. 2023. Diversity, Equity and Inclusion in the Workplace. May 17. Washington, DC: Pew Research Center.

LDF [Legal Defense Fund]. 2023. Affirmative Action in Higher Education: The Racial Justice Landscape After the SFFA Cases. New York: NAACP Legal Defense & Educational Fund, Inc. Online at www.naacpldf.org/wp-content/uploads/2023_09_29-Report.pdf.

LDF. 2024. The Economic Imperative to Ensure Equal Opportunity: Guidance for Employers, Businesses, and Funders. New York: NAACP Legal Defense & Educational Fund, Inc. Online at www.naacpldf.org/wp-content/uploads/2024-02-01-Aff-Axn-Economic-Guidance-2.pdf.

NACME [National Action Council for Minorities in Engineering, Inc]. 2008. Synergies Annual Report. New York, NY.

NASEM [National Academies of Sciences, Engineering, and Medicine]. 2016. Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways. Washington, DC: The National Academies Press.

NASEM. 2019. Minority Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce. Washington, DC: The National Academies Press.

NCSES [National Center for Science and Engineering Statistics]. 2023. Diversity and STEM: Women, Minorities, and Persons with Disabilities 2023. Special Report NSF 23-315. Alexandria, VA: National Science Foundation.

NSF [US National Science Foundation]. 2024. NSF 24-563: Louis Stokes Alliances for Minority Participation (LSAMP): Solicitation.

Palid O, Cashdollar S, Deangelo S, Bates C, Bates M. 2023. Inclusion in practice: A systemic review of diversity-focused STEM programming in the United States. International Journal of STEM Education 10: article no. 2.

Rock D, Grant, H. 2016. Why diverse teams are smarter. Harvard Business Review, Nov 4.

Samuels J, Shirazi Z. 2023. The high court didn't kill DEI at work. Employers shouldn't waver. Bloomberg Law, July 11. Online at news.bloomberglaw.com/us-law-week/the-high-court-didnt-kill-dei-at-work-employers-shouldnt-waver.

Sarraju A, Ngo S, Rodriguez F. 2023. The leaky pipeline of diverse race and ethnicity representation in academic science and technology training in the United States, 2003-2019. PlOS ONE 18(4):e0284945. Online at 10.1371/journal.pone.0284945

Setty, R. 2023. New EEOC democrat says workplace diversity has panel backing. Bloomberg Law, Nov 7. Online at news.bloomberglaw.com/daily-labor-report/new-eeoc-democrat-says-workplace-diversity-has-panel-backing.

Stout R, Archie C, Cross D, Carman C. 2018. The relationship between faculty diversity and graduation rates in higher education. Intercultural Education 29(3):399–417.

Strayhorn TL .2008. The role of supportive relationships in facilitating African American males' success in college. NASPA Journal 45(1):26–48.

Thacker I, Seyranian V, Madva A, Duong N, Beardsley P. 2022. Social connectedness in physical isolation: Online teaching practices that support underrepresented undergraduate students' feelings of belonging and engagement in STEM. Education Sciences 12(2):1–22.

True-Funk A, Poleacovschi C, Jones-Johnson G, Feinstein S, Smith K, Luster-Teasley S. 2021. Intersectional engineers: Diversity of gender and race microaggressions and their effects in engineering education. Journal of Management in Engineering 37(3).

Tsui L .2007. Effective strategies to increase diversity in STEM fields: A review of the literature. The Journal of Negro Education 76(4):555–81.

UCMP [University of California Museum of Paleontology]. Nd. Understanding Science 101: The Social Side of Science: A Human and Community Endeavor, accessed July 23, 2024.

Valez ED, Heuer R. 2023. Exploring the Educational Experiences of Black and Hispanic PhDs in STEM. Washington, DC: RTI International Research Institute.

White BJ, Fulton JS. 2015. Common experiences of African American nursing students: An integrative review. Nursing Education Perspectives 36(3):167–75.

Co-chairs of the NASEM diversity science report present a candid conversation in which they discuss a systems approach to tackling systemic racism, lived experience, implicit bias, and their perspectives on the wide-ranging recommendations of the report.

The NASEM Diversity Science Report:

Going Beyond Mere Participation Numbers

Gilda A. Barabino

Susan T. Fiske

Gilda A. Barabino and Susan T. Fiske

We co-chaired the National Academies of Sciences, Engineering, and Medicine (NASEM) consensus study *Advancing Antiracism, Diversity, Equity, and Inclusion in STEMM Organizations* (NASEM 2023). The report makes evidence-based recommendations grounded in diversity science (Plaut 2010) and practitioners' experience. The list below paraphrases the report's recommendations:

2-1. Predominantly White institutions (PWIs) can gain from understanding the academic success of MSIs (minority-serving institutions), such as historically Black colleges and universities (HBCUs). Mutually beneficial partnerships might result.

3-1. To advance anti-racism and diversity, equity, and inclusion (DEI) requires new data on education paths for individuals in STEMM.

5-1. STEMM leaders should improve numbers of underrepresented minority (URM) trainees and improve their experience of belonging; **(5-2)** facilitate contact among URM ingroup peers; **(5-3)** facilitate mentoring; and **(5-4)** set norms of inclusion.

Gilda A. Barabino (NAE, NAM) is president and professor of biomedical and chemical engineering, Olin College of Engineering. Susan T. Fiske (NAS) is Emerita Eugene Higgins Professor, Department of Psychology, and School of Public and International Affairs, Princeton University.

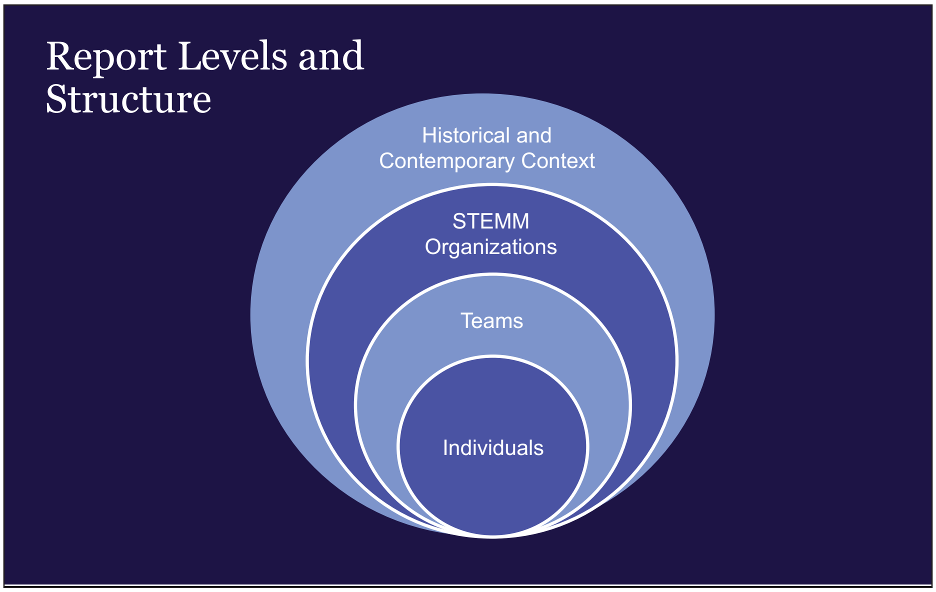

FIGURE 1

6-1. Organizational gatekeepers should be accountable for the gatekeepers' own overall patterns of diversity or bias in the organization units they manage.

7-1. In both academia and industry, management should create explicitly interdependent teams, with incentives for performing well together.

8-1. Organizations should review criteria for entry, recognition, and promotion; **(8-2)** change agents should expect resistance to any proposed changes.

9-1. Organizations should evaluate their culture and do research advancing anti-racism.

This article features our conversation about the report's basis for generating its recommendations and conclusions. We begin by noting the history of systemic racism and then describe its continuing legacy in STEMM organizations. We examine the report's relevance for engineers: analyzing racism as systemic, the evidence from diversity science, the approach of lived experience, awareness of bias, and working at all levels (societal, organizational, leadership, gatekeepers, teams, and individuals). Finally, we discuss next steps.

Our discussion harkens back to our approach to co-chairing the study, as we shared in the study's preface. Undaunted by the challenges associated with using evidence-based action to remedy systemic inequities, "we tackled our charge to identify racist and biased conditions that create systemic barriers and impede the full talent pool of our nation from pursuing and advancing in STEMM careers." It is our hope that despite the inherent discomfort in tackling racism, readers engage the evidence-based, actionable strategies and recommendations in the report in order to "make STEMM settings more diverse, inclusive, and equitable—and more anti-racist."

Systemic Racism

Susan Fiske: As a non-engineer, I've heard a lot about systems analysis. Could you explain in broad-brush ways how this report would fit an engineering approach, a systems analysis of the racism problem.

Gilda Barabino: I like that idea precisely because people do not spontaneously take a systematic approach to these issues. People are looking for a magic wand or just one way to solve a complex problem. In something as complicated as anti-racism and DEI we need a systems approach. We need multi-pronged efforts. We need to understand the interrelationships and interconnectedness of issues, environments, people, backgrounds, identities, systemic policies, and habitual practices—and how they work together in a system. We need systems thinking to seek and to implement solutions.

Fiske: That's a really rich answer. One figure in the report (see figure 1) illustrates a system, breaking it down by level of analysis. It starts with individuals, then teams, gatekeepers, organizations, and, finally, society. Different causal factors would be relevant in each of those cases. It would be a mistake for people to think that implicit bias training for individuals is the answer to systemic racism. They are different levels of analysis, different levels of aggregation. It's like putting a cork in a leak thinking that that's going to change everything. People need to figure out the root causes of leakage from the system.

Diversity Science, a Hard Science, Benefits from the Advice of Those Studied

Barabino: One of the things that comes to my mind for you, Susan, is that I think that we don't do a good enough job of engaging social scientists with the other scientists and engineers to study our systems. We tend to remain siloed rather than taking an interdisciplinary, collaborative approach to solving the problem.

I'll share one of the reasons why I began collaborating with social scientists: They often study other scientists and engineers without being those kinds of scientists and engineers themselves. Sometimes, groups of diversity scientists don't include any URMs. So, they're doing their best to pose and frame the questions to study these underrepresented groups. But maybe the questions would be posed and framed better if the people that they're studying had some input into how they're being studied. For example, interviewing highly successful STEMM professionals about their lived experiences reinforces the diversity science takeaways but can also provide additional insights.

Let me further illustrate. While on my second sabbatical leave, I encountered a learning science professor and a psychology professor who were conducting a study on women's experiences in research laboratories. Intrigued, I asked if their study would differentiate between the experiences of majority and non-majority women, and the answer was no. Knowing that I brought a different perspective from my own lived experience as a Black woman in engineering, I suggested another study focused on women of color. The study I conducted in collaboration with my colleague and psychology professor Kareen Malone resulted in a publication in *Science Education*, "Narrations of Race in STEM Research Settings: Identity Formation and its Discontents."

Fiske: I am reminded of the disability activists' saying, "No about-us, without us." Diversity scientists count themselves as scientists, but we don't have all the answers. Diversity science involves both basic science and practice. But the larger point you raise is a perennial basic-science question: getting advice from people who are living the situation. What kinds of things are coming up that are not covered by the basic science of diversity? For example, the lived experience of exclusion—say, being ignored for study groups or not knowing about test banks could provide mechanisms to link belonging and performance (NASEM 2023).

Do you think understanding that diversity science is a science would be surprising to most engineers and most members of the National Academy of Engineering?

Barabino: Science and engineering get defined too narrowly, and who is seen as a scientist or engineer gets defined too narrowly as well. On the science and engineering side, although plenty of people care about these issues, there's not a real understanding of diversity science at all. There's just not.

Fiske: I know engineering has infrastructure (grants, fellowships, programs) to broaden participation, often based on experience-based hunches about what should work. In diversity science, we test model-driven hypotheses. We have theories, we have frameworks, we do experiments, and we do surveys. And the biggest problem is measurement. So, we refer to it as a hard science.

People are looking for a magic wand or just one way to solve a complex problem. In something as complicated as anti-racism and DEI we need a systems approach.

Individual Awareness of Individual Bias

Fiske: For one example of the measurement challenge at the individual level of analysis: It's difficult to get people to talk about their feelings and reactions to other people without them stage-managing themselves. This is why diversity science has invented several indicators of individual bias, more or less explicit, with or without compunction, emotional or not (Banaji and Greenwald 2016; Eberhardt 2019, Fiske 1998; Richeson et al. 2024; Shelton and Turetsky 2024). Multiple indicators help triangulate on the self-report problem. But even before that, they have to know they are biased. So, the first question is, are they aware of their prejudice?

Barabino: That's right.

Fiske: And many people are not aware. Then, even if they're aware of their prejudiced attitudes on some level, will they tell us? After all, it makes them look bad. (That's one kind of reason that we call diversity science a hard science.)

Barabino: That makes sense. But as we're talking, the power of how you and I can come together to point out some of these challenges—we could be filling a void. We could say, "Hey, all you folks mean well, but here's something that all of you miss." And I do think the existence and impact of prejudiced attitudes and behaviors (intended or not) are continually overlooked, not just by well-meaning STEMM professionals, but also by well-meaning diversity scientists.

Fiske: I think it's shortsighted to give people training just in implicit bias (Banaji and Greenwald 2016).

Barabino: Very shortsighted.

Fiske: I mean, if you have the experience of taking an implicit bias test (Banaji and Greenwald 2016), and you find yourself making bias a pattern, or exhibiting overall bias, most people have a moment of shock, like, "whoa." But you have to be open to taking the test and believing that bias is a real thing and not just some made-up party game.

Barabino: Once, when I had a group of engineers take the implicit bias test, they made comments like, "This is bogus." "This is all fake, not measurable." So, as you said, they have to believe bias is a real thing. In their minds, they are telling themselves, "It's not a real thing, so I don't have to pay attention to it."

Returning to the Big Picture: Working at All Levels

Fiske: One way to tell if implicit bias is real is this massive online database of millions, literally millions, of people responding to implicit bias tests, and you can trace the county that they live in. With large numbers, the county level of implicit bias predicts discrimination against minoritized people in that county. The sort of aggregated individual persons' bias predicting a general pattern of biased decision-making is typical in that ecology. So implicit bias is real if you look at aggregates like county-wide indicators of bias.

Barabino: That's right.

Fiske: But that means that in STEMM organizations, if you looked at the average level of implicit bias, you would be able to predict their overall patterns. At the individual level, it's not so obvious because it's automatic.

Importantly, there are other ways that racism is not likely to be on an individual's radar screen besides it being automatic. That's what they call implicit bias, but it's also ambiguous. People favor their own tribe, as much as, or more than, disfavoring others. They say, "Oh, well, I just don't know that she's our kind of person. She doesn't feel like people like us." And so, it's that feeling of, "Who's familiar? Who's like me?" People like themselves. So, the ambiguity is: Favoring your own has this collateral damage of leaving out the others (Brewer 1999). After automaticity and ambiguity, the last part of it is the ambivalence; two forms of prejudice are disrespecting but liking (paternalism) or disliking but respecting (envy) (Fiske et al. 2002).

All this means that individuals are unlikely to be able to track their own bias, so someone else has to notice the person's overall patterns of decision-making. The organizational level, the context, may be a better predictor than the individual.

Lived Experience of Individuals in the World

Barabino: The context of everything matters, and lived experience matters. There's something valuable about hearing from the people who authentically can speak to some of the toll that racism takes. One need not literally walk in someone else's shoes in order to empathize and speak to their experiences, but there must be the capacity to hear and to learn and to enhance one's understanding through scholarship, data, and other ways of knowing.

Fiske: For example, in the field of diversity science broadly defined, about three decades ago, maybe four, all the White people in the field believed that Black people must have low self-esteem because how could you be subjected to the kind of garbage and not have low self-esteem (Allport 1954)? Of all the different ethnic and racial groups, Black people have some of the higher self-esteem, because when people take a piece of them, they say, "That person's just a bigot." So, you can have high self-esteem and just not care about what the public regard for your group is (Crocker and Major 1989). And the White people said, "Oh, I didn't know." So, there's a lot of stuff like that that's been found out the hard way. Different ethnic groups respond differently. Some groups tend to care a lot about what other people think of them some don't.

Barabino: Yes, you're right about that.

Fiske: So, if their group is seen in low regard, they feel it personally. But Black people have learned; it's like the conversation that you have with your kid before they go to elementary school.

Barabino: Exactly.

Fiske: I mean, that's what I gather.

Co-Chairs Uniting Science, Practice, and Lived Experience: How to Create Metrics Together

Barabino: Our chairing that study together was phenomenal because we meshed our strengths. We also brought our own perspectives in a way that made the overall product richer.

Fiske: How very pragmatic.

Barabino: Absolutely. And it's hard for engineers and scientists to accept and be guided by what is perceived as being based on feelings rather than data and metrics. But feelings and attitudes are important and need to be acknowledged even if it's hard to quantify them.

Fiske: Diversity scientists quantify them.

Barabino: To some extent, I guess. I think the readers need to understand, what does that mean?

Fiske: I'm thinking of an example of a feeling thermometer (Allport 1954). It's a very simple form of measurement of feeling toward groups. On a scale of 0 to 100, how do you feel about Native Americans? Or how do you feel about White people from Europe? And so that's a very simple way, and it's sort of engineering.

Barabino: Then all of a sudden, engineers are thinking, "Hmm. Yeah, there's some metric to it." They're always looking for metrics for—

Fiske: Everything. That's my instinct. And we look for reliability and validity.

Engagement at All Levels

Barabino: I like that concept. But that's not the only way to engage. Let's think of different ways to engage that are likely to be effective. For example, in speaking with a representative from the National Museum of African American History and Culture about our study, it came up that they do STEM days, and we were invited to participate.

Fiske: We're not science-fair material.

Barabino: True. But maybe we could be involved in a seminar series or some other event or other way of connecting. It would be wonderful to connect to individuals' personal experiences. An example of one of many connections for me is the museum exhibit about the Polar Bears, the exercise group that gathers on Inkwell Beach on Martha's Vineyard, and my own participation with the Polar Bears during my vacation.

Fiske: How cool. I've missed that somehow.

Barabino: And so, my point is that in bringing our report to life, we draw upon the ways people, places, and times are connected. Just like me seeing the exhibit about the Polar Bears. Because connections like that, Susan, to me, are also dissemination. That's getting in different rooms, reaching different audiences, and elevating the discussion about the report. I think that's a big deal.

Fiske: The people we want to reach are such a varied group of people in terms of what they do, but I bet they've all been subjected to bias training. Informing people that bias is not what they think it is and to consider the larger context is important (Dobbin and Kalev 2022; Paluck et al. 2021).

Barabino: The other thing that I think is helpful for us is our constant ability to show how we, a diversity scientist and a practitioner, plan together. And that's how the committee built our recommendations.

The context of everything matters, and lived experience matters.

Many Paths to Antiracism, Across Levels

Fiske: The committee had a consensus to use strong language. This report uses the term "antiracism" frequently throughout. We intentionally included the word "antiracism" in the report title, and it was also a key part of our statement of task. The committee defined antiracism as an intentional set of actions that dismantle and disrupt racism. These actions may incorporate a range of behaviors, from reworking policies, to developing new systems, or changing practices. No matter what that specific behavior is, the goal is to initiate positive change.

In the report, the committee included more than 25 evidence-based conclusions and recommendations. When developing our recommendations, we wanted to be sure that they would be consistent with and true to the principles of being antiracist. We authored recommendations that people can pick up and put into action, all with the goal of making STEMM more equitable, inclusive, and diverse. Over the course of this report, we hope people come away with the message that there is not just one, but many potential paths to successful and sustainable change.

The report offers such a rich set of ideas and strategies; we think a book group or a weekly seminar would be a useful way to absorb and discuss these ideas.

Next Steps

Barabino: Currently, we are switching gears from talking about what is published in the report to talking about the next steps. This report was never intended to sit on a shelf. We want this report to inspire a body of future transformational and groundbreaking work. We are hopeful that this will be the first of many subsequent reports related to advancing antiracism, diversity, equity, and inclusion in STEMM.

When you look at our report, it is evident that much work remains to be done. In the last chapter, the committee authored a robust research agenda that outlines the many research questions that still need to be answered. As the committee recognized, the work that comes next should not only fill these gaps, but it should propel the field forward in ways that are innovative, challenging, and necessary.

There is much cause to be optimistic, and I am particularly optimistic about the continued impact and potential legacy this report can have. We look forward to other wonderful opportunities for all like-minded participants, in-person and remotely, to act on the lived experiences and evidence-based recommendations.

References

Allport GW. 1954. The Nature of Prejudice. Boston: Addison-Wesley.

Banaji MR, Greenwald AG. 2016. Blindspot: Hidden Biases of Good People. New York: Bantam.

Brewer MB. 1999. Psychology of prejudice: Ingroup love and outgroup hate? Journal of Social Issues 55(3):429–44.

Crocker J, Major B. 1989. Stigma and self-esteem: Self-protective properties of stigma. Psychological Review 96(4):608–30.

Dobbin F, Kalev A. 2022. Getting to Diversity: What Works and What Doesn't. Cambridge, Massachusetts: Harvard University Press.

Eberhardt JL. 2019. Biased: Uncovering the Hidden Prejudice that Shapes What We See, Think, and Do. New York: Penguin Random House.

Fiske ST. 1998. Stereotyping, prejudice, and discrimination. In: The Handbook of Social Psychology, 4th edition, 357–411. Gilbert DT, Fiske ST, Lindzey G, eds. New York: McGraw-Hill.

Malone KR, Barabino GA. 2008. Narrations of race in STEM research settings: Identity formation and its discontents. Science Education 93(3):485–510.

NASEM [National Academies of Sciences, Engineering, and Medicine]. 2023. Advancing Antiracism, Diversity, Equity, and Inclusion in STEMM Organizations: Beyond Broadening Participation. Barabino GA, Fiske ST, Scherer LA, Vargas EA, eds. Washington, DC: The National Academies Press.

Paluck EL, Porat R, Clark CS, Green DP. 2021. Prejudice reduction: Progress and challenges. Annual Review of Psychology 72:533–60.

Plaut VC. 2010. Diversity science: Why and how difference makes a difference. Psychological Inquiry 21(2):77–99.

Richeson JA, Rucker JM, Brown X. 2024. Race and racism. Handbook of Social Psychology, 6th edition. Gilbert DT, Fiske ST, Finkel E, Mendes WB, eds. Princeton: Situational Press.

Shelton JN, Turetsky KM. 2024. Diversity. Handbook of Social Psychology, 6th edition. Gilbert DT, Fiske ST, Finkel E, Mendes WB, eds. Princeton: Situational Press.

The effectiveness of DEI efforts to impact the inclusion and advancement of women in STEMM fields rests on greater synergy between an organization's stated goals and outcome-focused efforts, including mentorship and allyship.

Enhancing Diversity, Equity, and Inclusion through Mentorship and Allyship for Career Advancement and Retention of Women in STEMM

Audrey J. Murrell and Samuel Allen

Audrey J. Murrell

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In an era and environment marked by persistent social inequalities, some organizations are upholding their commitment to diversity, equity, and inclusion (DE&I) through various efforts. These efforts are not just about recruitment, but about ongoing actions to ensure retention, advancement, and overall well-being across all aspects of diversity. This is especially true for women in science, technology, engineering, math, and medicine (STEMM) fields who remain underrepresented, particularly in senior-level positions. While public statements of commitments to DE&I are needed, the effectiveness of these efforts rests not only on a publicly stated commitment to recruit diverse individuals into the organization but also on ongoing actions to ensure retention, advancement, and well-being. These actions must be part of a long-term focus on transforming systems and cultures that perpetuate unequal organizational distributions of psychological, social, and material power. This long-term focus is crucial to ensure that diversity initiatives do not just articulate goals and desires to address inequality issues but achieve them. Our collective responsibility is to ensure that these actions are not just temporary measures but part of a sustained effort to create a more inclusive and equitable environ-

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ment. We suggest that organizations pay close attention to what actions, programs, and efforts serve as positive (or negative) signals of their commitment to DE&I goals and objectives to ensure positive organizational and leadership impact.

An over-emphasis on sponsorship alone can send an unintended message that women are seen merely as a "resource" to the organization with the primary goal of producing tangible or measurable outcomes that benefit the organization and its reputation.

Inconsistency between publicly stated diversity goals or objectives and their outcomes can even produce "backfire" that can block the achievement of stated DE&I goals (Leslie 2019) and generate skepticism among intended beneficiaries (Wilton et al. 2020). Burnett and Aguinis (2024) argue that DE&I backfire can take place when mixed results and/or negative unintended consequences occur. The inconsistencies often occur when stated goals and outcomes are either not realized (e.g., a lack of greater advancement of women or people of color into leadership roles) or create unintended outcomes that do not match the stated goals (e.g., women advanced to leadership only in high-risk positions). Thus, backfire refers to the negative consequences of diversity efforts that either fail to achieve the intended outcomes or achieve outcomes that create undesirable consequences (Leslie 2019). Backfire can also occur when diversity efforts unintentionally have a negative impact on those identified as beneficiaries (e.g., glass ceilings or glass cliffs for women in leadership).

This is especially problematic for advancing women and people of color in non-traditional careers in STEMM fields that historically lack diversity, particularly in leadership and at senior levels (Fagan and Teasdale 2021). Among the various strategies and approaches to enhancing diversity within STEMM fields both in terms of access and advancement, many leaders and scholars advocate for the use of mentors and sponsors as necessary and beneficial for supporting as well as advancing the careers of women and underrepresented groups within STEMM (Dahlberg and Byars-Winston 2020). However, others argue that women are over-mentored and under-sponsored, which may benefit recruitment efforts but does not address ongoing barriers to career advancement, leadership development, and personal well-being (Griffeth et al. 2021).

The Dual Importance of Mentorship and Sponsorship

While people discuss or define mentorship and sponsorship in various ways, we rely on the work by Higgins and Kram (2001) for our definition. They advocate for a broader view of mentoring as developmental relationships or "mentoring functions" that can include both career and psychosocial functions or support. Their work identifies "sponsorship" as the class of developmental relationships focusing on strictly career-oriented functions, including providing support and/or advocacy for career advancement. Psychosocial support, the other dimension of Higgins and Kram's (2001) conceptualization of mentoring, is how mentorship is most typically presented in research and includes functions such as advice, social support, counseling, acceptance, and validation.

While the diverse nature of mentoring relationships has been acknowledged, much has been written and researched regarding the specific role that sponsorship plays in advancing the careers of women, especially in STEMM fields. For example, Hewlett (2013) argues that mentoring alone cannot create meaningful change for women and underrepresented groups. Meaningful change must include a significant focus on sponsorship. Others agree with Hewlett that having access to powerful and influential sponsors in senior positions is important, especially for increasing and sustaining diversity for women and people of color (NASEM 2020). Sponsors have been shown to help women seek out opportunities for development and advancement in the organization while receiving advocacy from high-status and influential individuals (Hewlett 2013). Some also argue that sponsorship can uniquely increase the visibility of women seeking leadership roles (Bromley and Powell 2012; Mor Barak et al. 2022). Sponsorship can help women access important and high-profile opportunities or projects that develop key skills and place them on the radar when opportunities for advancement arise (Ayyala et al. 2019). Thus, connecting women to sponsors through organizational programming is seen as essential for advancing women in underrepresented areas in STEMM fields (Bilimoria and Singe 2019).

While implementing programs focusing on sponsorship for women's advancement in STEMM is important, we suggest that it represents only part of the necessary support and advocacy for women's advancement and well-being. Any efforts involving sponsorship-focused programs must consider how they achieve synergy with key organizational goals, especially those focused on achieving diversity, equity, and inclusion. We suggest that an over-emphasis on sponsorship alone can send an unintended message that women are seen merely as a "resource" to the organization with the primary goal of producing tangible or measurable outcomes that benefit the organization and its reputation. While not true for all organizational DE&I efforts, too much attention to the "return on investment" of sponsorship can signal that the organization views the advancement of women via a purely transactional or what some refer to as a "resource mindset" that might be beneficial for the organization but can potentially send mixed signals to women both internally and externally (Ely and Thomas 2020; Millwater and Yarrow 1997). Tangible returns on an organization's efforts to enhance women's careers are important; however, a "resource mindset" can create a narrow singular focus on sponsorship only, which can be insufficient to support the full range of organizational goals, such as inclusion, belongingness, and the retention of women, especially at top levels within an organization (Blaique et al. 2023). We argue that organizations must be cautious about unintentionally shifting their focus toward a pure resource mindset and include other important factors such as belongingness, identity, and inclusion, which are often referred to as part of a value mindset. Acknowledging that mentoring must include a balance between both a resource and a value mindset is an important broadening of the meaning and impact of these significant developmental relationships. This should stimulate an expansion of mentoring outcomes beyond career advancement and include mentoring outcomes such as learning, growth, inclusion, belongingness, and innovation.

With this expanded view of mentoring as the inclusion of both a resource and a value mindset, it is also necessary for organizations and their leadership to be clear in the purpose, focus, and desired outcomes of mentoring efforts. How leaders define the desired goals of mentoring in achieving DE&I objectives is important for both achieving those goals and signaling their commitment to stated DE&I goals to internal and external stakeholders. This is akin to what is referred to within the literature as "organization signaling," which includes organizational messages and statements by leaders that, together with actions, indicate either a commitment or lack of commitment to stated goals (Westra 2021). Inconsistency between publicly stated goals and objectives can be viewed by those inside and outside of the organization as a signal for a lack of commitment or evidence of hypocrisy related to DE&I initiatives (Westra 2021). If women lack advancement into senior leadership roles yet the organization makes frequent statements about DE&I commitment, this can produce a negative signaling effect, which can have detrimental consequences for the future engagement and retention of women and other underrepresented groups.

Importantly, leaders act as pivotal organizational signalers that can provide either confirming or discrediting evidence of the valued goals of the organization, including those focused on advancing women into leadership roles. Leaders who are seen as signalers not only send messages that impact the organization's external reputation but also shape the organization's internal culture, especially for people from underrepresented groups. If those messages are inconsistent with the organization's actions, it can negatively impact individuals' perceptions of the underlying meaning or rationale for the stated DE&I objectives and erode feelings of belonging, identity, and authenticity among individuals in the organization (Wilton et al. 2020). Persistent inconsistencies in stated goals versus actions can also produce backfire responses among key stakeholders that lessen the overall effectiveness of these important efforts (Burnette and Aguinis 2024).

Effective use of both sponsorship and mentorship to support DE&I efforts such as recruitment, retention, and advancement can and should signal the authenticity of an organization's commitment to inclusive developmental efforts for women and people of color (Yin 2024). In order to address more than recruiting women into STEMM positions via sponsorship efforts, we suggest that equal attention be paid to retention and advancement goals by not only including traditional mentoring efforts but also including emerging forms of allyship as one part of the full range of development relationships within the organization and a signal of the organization's commitment to realizing its DE&I objectives. Thus, organizational signaling should be seen as important in our ongoing efforts to advance women in STEMM.

Signaling Support for Advancing Women in STEMM

Organizational signaling is important for clarifying, advancing, and engaging both internal and external stakeholders. Some argue that leaders across all levels of the organization should serve the role of a "signaler" in their public statements. Their ongoing actions must be consistent with stated overall organizational goals and those focused on diversity, equity, and inclusion. Westra (2021) provides important contributions to the notion of consistency between public moral discourse and organizational goals, values, ethics, and valued outcomes. How organizations and their leadership engage in signaling, especially with key stakeholders, can impact key outcomes such as engagement, reputation, ethical behavior, and overall trust in leadership (Connelly et al. 2011). If organizations promote DE&I yet lack retention, meaningful advancement, and empowerment of women, it signals a break in the linkage between stated values and actions. Prior research has identified groups of factors that contribute to the "leaky pipeline" of women in STEMM fields, such as the existence of an unfriendly work environment, poor accommodation of family obligations, sexual harassment, disparities in pay, biased job duties and appointments, and varying approaches to evaluating work (Hill et al. 2010).

Organizations can signal inclusion, well-being, and belongingness for women and people of color by focusing on a diverse range of developmental relationships that must also include allyship.

Women's underrepresentation in the workplace has also been attributed to biased selection processes favoring men in certain job roles and positions and subjective and arbitrary advancement opportunities (Begeny et al. 2020). Even though numerous findings and recommendations of studies on equal opportunities and unfair discrimination have been considered and improvements have been made in many organizations, some still argue that women's working representation, especially in STEMM fields, has not yielded significant advancement for over 10 years (Fouad and Santana 2017). Thus, signaling in the context of DE&I is important, and stated commitments are an avenue through which organizations can signal their support for, perspective on, and actions surrounding important diversity-related issues. Without being embedded in the organization, external actors can only perceive an organization's position on diversity issues through the signals it sends, making these statements an important communication method for an array of external and internal stakeholders, including potential employees, clients/customers, leaders, partners and investors/funders.

For example, research shows that the presence of DE&I statements as signals of organizational culture and strategy can produce significant alterations in stock returns, particularly in the days immediately following the announcement of DE&I commitments for publicly held companies (Li et al. 2022). In addition, a demonstrated commitment to diversity-related issues results in higher perceived organizational support for diversity and inclusion, higher levels of organizational attachment, and firm-level revenue gains (Corrington et al. 2022). On the other hand, some studies have found that the widespread presence of diversity statements without demonstrated results undermines organizational attractiveness, especially in employees' eyes among organizations that utilize the statements (Varty 2022). This is similar to findings showing that signaling a commitment to DE&I without supporting that commitment in both policy and practice leads to a phenomenon known as "diversity dishonesty," a belief that an organization is falsely inflating its commitment to diversity-related issues through statements and signals (Wilton et al. 2020).

We contend that developing a comprehensive set of developmental programs throughout the organization that are aligned with the organization's stated DE&I goals should include a range of efforts that signal and actualize a commitment to these stated goals. Based on this perspective, this synergy should include a diverse portfolio of both mentorship and sponsorship programs. Including both can signal a commitment not only to advancement but to other key outcomes, such as perceptions of organizational support, feelings of belongingness, and the experience of psychological safety, especially among members of underrepresented or minoritized groups. However, these latter outcomes are important and may not be supported by a singular focus on sponsorship alone. Building this diverse portfolio should include various developmental programs that include mentorship, sponsorship, and allyship as tools for achieving an organization's DE&I goals and supporting learning, growth, inclusion, and innovation (Yin 2024). However, organizations have traditionally only focused on sponsorship and mentorship. Therefore, we make a case that organizations can signal inclusion, well-being, and belongingness for women and people of color by focusing on a diverse range of developmental relationships that must also include allyship.

The Need for Inclusive Allyship

To achieve this important goal, we make a case for the importance of allyship in efforts to attract, retain, and advance women in STEMM fields, especially at leadership levels of the organization, as a complement to ongoing sponsorship and mentorship efforts. Like Creary (2023), we employ a critical theory definition of allyship as relational tools that focus on actions and systems to challenge, transform, or redefine traditional power structures to remove barriers to access, opportunities, inclusion, and equal participation. Research and organizational practice adopting this critical theory perspective on allyship make DE&I goals by intentionally including marginalized and privileged group members as equal allies to acknowledge that anyone, regardless of their location in the power hierarchy, can challenge or collaborate to create change throughout the organization.

We draw on both Creary's (2023) and Dang and Joshi's (2023) view of allyship as any actions by those within an organization (e.g., employees, co-workers, leaders, etc.) that challenge existing power structures and support others belonging to disadvantaged and/or underrepresented social groups. Allyship aims to promote equity and inclusion, especially for those disadvantaged, marginalized, or overlooked by traditional standards, perspectives, or evaluation methods. This means allyship fundamentally aligns with organizational diversity and inclusion's explicit focus and goals (Creary 2023). While sometimes acknowledged to include sponsorship-related activities within the organization, allyship can have a broader reach that extends to engagement and advocacy efforts within the broader profession for women and members of diverse social groups. Allyship is purpose-driven, intentional, transformational, and uniquely tied to the specific work of diversity, equity, and inclusion. Allyship involves a set of ongoing, action-oriented, beneficiary-centered relationships that are unique in that they challenge unequal power systems, unlike traditional approaches such as limiting access to development relationships through a singular focus on sponsorship (Bhattacharyya et al. 2024). Thus, enhancing and achieving DE&I goals and objectives for women in STEMM careers can be supported and enhanced by creating a diverse portfolio of developmental efforts that include sponsorship, mentorship, and allyship.

It is also important to note that allyship is not always defined by the characteristics of the person engaged in these efforts (e.g., race, gender, social class, identity, etc.) but by the intended beneficiaries of necessary actions. This means that the diversity of those engaged in allyship is an important indication or signal of the range of support for DE&I efforts throughout the organization. For example, if the only allyship efforts are being made through women's efforts to enhance DE&I within the organization, then some may question its commitment to its stated goals. Suppose those individuals who engage in allyship differ across demographics, characteristics, levels, or positions in the organization. This can serve as a strong and positive signal of an organizational culture that puts their stated DE&I goals and targeted outcomes into action. Making this distinction is important for meaningful synergy of specific actions or efforts with the organization's DE&I strategy. For example, previous perspectives that characterize various types of mentoring-related efforts as part of DE&I efforts suggest they are purely transactional (i.e., prioritizing a rigidly defined set of short-term, strictly career-oriented goals) rather than developmental (i.e., prioritizing long-lasting relationships that emphasize personal development alongside career-related objectives), which can have limited impact for achieving organizational diversity and inclusion goals (Schenk et al. 2021). However, research on allyship can be seen as distinct from yet complementary to sponsorship in supporting the stated goals of diversity, equity, and inclusion within an organizational context without barriers of status, power, and rank within developmental relationships (Phillips et al. 2024).

Thus, if we aim to create more opportunities to increase the representation and advancement of women in STEMM fields, then our efforts must include programs and actions that not only send a strong signal for diversity but also ensure the inclusion and sense of belongingness throughout the organization and especially across all levels. One of the most frequent tools used to support the recruitment, retention, and advancement of women in STEMM involves a range of mentoring programs and initiatives (NASEM 2019). However, while mentoring and sponsorship can both demonstrate benefits for individual development and support diversity efforts, their effectiveness can be reduced by embedded organizational structures and hierarchies, making these efforts instrumental rather than developmental. In addition, the complicated nature of hierarchical mentoring relationships can often occur when organizations focus exclusively on sponsorship, especially within the context of DE&I efforts.

Rather than arguing that women are over-mentored and under-sponsored, we should work toward a future where women can access a diverse portfolio of mentors, sponsors, and allies.

Instead of using one-time mentoring efforts to signal an organization's commitment to diversity and inclusion, we suggest focusing on the distinction between a resource versus a value mindset as part of designing and delivering effective mentoring efforts (Yin 2024). Developing a strong culture that includes allyship as part of other mentoring efforts is necessary for creating this mindset throughout the organization toward the advancement and well-being of women at all levels and functions. It will also send a strong external signal about the authenticity and legitimacy of organizational goals focused on DE&I, especially for women underrepresented in STEMM fields. Developing mentoring efforts that include allyship is especially important because it can impact traditional organizational outcomes (e.g., efficiency, effectiveness, profitability) and broader outcomes such as retention, citizenship, innovation, and belongingness (Douglass 2024). Taking the lessons learned from research on allyship and including them within any efforts to advance women in STEMM is an important step toward enhancing the effectiveness of ongoing DE&I efforts.

For example, Murrell, Blake-Beard, and Porter (2021) utilized peer mentoring to support the advancement and well-being of a group of African American leaders. Their findings show that these peer mentoring relationships often took the form of advocacy, empathic acknowledgment, and validation, which can be considered a form of peer allyship. In addition, they noted that these peer mentoring encounters often included identity work among these African American leaders, which are also examples of allyship that provide unique types of support and validation often absent within traditional hierarchical mentoring.

A Call for Greater Synergy

The effectiveness of DE&I efforts to impact the inclusion and advancement of women in STEMM fields rests on greater synergy between stated goals and outcome-focused efforts within the organization. Early work by Nadler and Tushman (1980) argued that in order to function effectively, organizations' key performance components—tasks, people, and structure—need to fit together logically and cohesively, even when the external environment may not be aligned with these objectives. This remains true given the complexity of today's organizations regarding mission, structure, culture, and impact and the ongoing societal debates over the mission, need, and impact of organizational DE&I efforts. The need for greater synergy as related to DE&I goals and outcomes is significant in today's complex environment, as lack of synergy can be a negative signal of organizational accountability, effectiveness, and overall commitment to stated goals such as DE&I (Bromley and Powell 2012).

Existing research shows that mentoring matters for effective employee and leadership development and for enhancing DE&I efforts. However, lack of synergy of mentoring efforts within the organization's portfolio of DE&I initiatives can limit mentoring's impact as a strategic tool for supporting women and people of color while building an inclusive culture throughout the organization (Ferdman et al. 2021). Developing a mentoring mindset must be a critical part of an organizational DE&I effort. Instead of one-shot programs or overemphasizing sponsorship efforts as the only solution, developing a comprehensive mentoring portfolio of programs, structures, and outcome metrics that align mentoring with DE&I is essential for achieving both short-term and long-term goals.

While allyship may exist and support the advancement of women in STEMM fields, this does not always mean that institutional barriers and ongoing complexities due to power dynamics, embedded structures, and resistant cultures will be erased. In fact, Creary (2023) cautions that, sometimes, organizational allyship initiatives can trigger anxiety among leaders within organizations due to the increased emphasis on disrupting the existing power structure and dynamics within the organization. This may lead to an unconscious or conscious effort to restrict and ultimately prevent the effectiveness of ongoing efforts of allyship to reduce barriers and create meaningful organizational change. The use of allyship efforts must be coupled with a focus on developing, advancing, and recognizing inclusive leadership throughout the organization (Ferdman et al. 2021). The effectiveness of DE&I efforts rests on the synergy of these important strategic efforts. This is especially true if we are to create and sustain meaningful change toward the advancement of women in STEMM fields, especially into leadership levels within the organization. Rather than arguing that women are over-mentored and under-sponsored, we should work toward a future where women can access a diverse portfolio of mentors, sponsors, and allies. This is key to women's advancement and overall well-being.

References

Ayyala MS, Skarupski K, Bodurtha JN, González-Fernández M, Ishii LE, Fivush B, Levine RB. 2019. Mentorship is not enough: Exploring sponsorship and its role in career advancement in academic medicine. Academic Medicine 94(1):94–100.

Begeny CT, Ryan MK, Moss-Racusin CA, Ravetz G. 2020. In some professions, women have become well represented, yet gender bias persists—perpetuated by those who think it is not happening. Science Advances 6(26):eaba7814.

Bhattacharyya B, Erskine SE, McCluney C. 2024. Not all allies are created equal: An intersectional examination of relational allyship for women of color at work. Organizational Behavior and Human Decision Processes 182:104331.

Bilimoria D, Singer LT. 2019. Institutions developing excellence in academic leadership (IDEAL): A partnership to advance gender equity, diversity, and inclusion in academic STEM. Equality, Diversity and Inclusion 38(3):362–81.

Blaique L, Pinnington A, Aldabbas H. 2023. Mentoring and coping self-efficacy as predictors of affective occupational commitment for women in STEM. Personnel Review 52(3):592–615.

Bromley P, Powell WW. 2012. From smoke and mirrors to walking the talk: Decoupling in the contemporary world. Academy of Management Annals 6(1):483–530.

Burnett L, Aguinis H. 2024. How to prevent and minimize DEI backfire. Business Horizons 67(2):173–82.

Connelly BL, Certo ST, Ireland RD, Reutzel CR. 2011. Signaling theory: A review and assessment. Journal of Management 37(1):39–67.

Corrington A, Fa-Kaji NM, Hebl MR, King EB, Stewart D, Alao T. 2022. The impact of organizational statements of support for the black community in the wake of a racial mega-threat on organizational attraction and revenue. Human Resource Management 61(6):699–722.

Creary SJ. 2023. Taking a "LEAP": How workplace allyship initiatives shape leader anxiety, allyship, and power dynamics that contribute to workplace inequality. Academy of Management Review, (ja), amr-2021.

Dang CT, Joshi A. 2023. On the plurality and politics of ally work: Liberalism and self, relational, and organizational ally work. Academy of Management Journal 66(5):1554–85.

Douglas JA. 2024. Effects of mentoring and belongingness in the clinical setting. Radiologic Technology 95(4):293–8.

Dover TL, Kaiser CR, Major B. 2020. Mixed signals: The unintended effects of diversity initiatives. Social Issues and Policy Review 14(1):152–81.

Ely RJ, Thomas DA. 2020. Getting serious about diversity: Enough already with the business case. Harvard Business Review 98(6):114–22.

Fagan C, Teasdale N. 2021. Women professors across STEMM and non-STEMM disciplines: Navigating gendered spaces and playing the academic game. Work, Employment and Society 35(4):774–92.

Ferdman BM, Prime J, Riggio RE, eds. 2021. Inclusive Leadership: Transforming Diverse Lives, Workplaces, and Societies. Routledge.

Fouad NA, Santana MC. 2017. SCCT and underrepresented populations in STEM fields: Moving the needle. Journal of Career Assessment 25(1):24–39.

Griffeth LL, Malik RF, Charas S, Randall N. 2021. Sponsorship: An intervention to accelerate women's career velocity. IUP Journal of Soft Skills 15(3):7–22.

Hewlett SA. 2013. Forget a Mentor, Find a Sponsor: The New Way to Fast-Track Your Career. Harvard Business Review Press.

Higgins MC, Kram KE. 2001. Reconceptualizing mentoring at work: A developmental network perspective. Academy of Management Review 26(2):264–88.

Hill C, Corbett C, St Rose A. 2010. Why So Few? Women in Science, Technology, Engineering, and Mathematics. Washington, DC: American Association of University Women.

Leslie LM. 2019. Diversity initiative effectiveness: A typological theory of unintended consequences. Academy of Management Review 44(3):538–63.

Li F, Lo C, Tang CS. 2022. Will Diversity Equity and Inclusion Commitment Improve Manufacturing Firms' Performance? A Signaling Theory Perspective on DEI Announcements. Dec15. Online at ssrn.com/abstract=4318187.

Meikle PA, Morris LR. 2022. University social responsibility: Challenging systemic racism in the aftermath of George Floyd's murder. Administrative Sciences 12(1):36.

Millwater J, Yarrow A. 1997. Partnership: A theoretical construct for developing professionalism in preservice teachers. Teacher Education Quarterly 24(1):23–36.

Mobasseri S, Kahn WA, Ely RJ. 2024. Racial inequality in organizations: A systems psychodynamic perspective. Academy of Management Review. Online at https://doi.org/10.5465/amr.2021.0446.

Mor Barak ME, Luria G, Brimhall KC. 2022. What leaders say versus what they do: Inclusive leadership, policy-practice decoupling, and the anomaly of climate for inclusion. Group & Organization Management 47(4):840–71.

Murrell AJ, Blake-Beard S, eds. 2017. Mentoring Diverse Leaders: Creating Change for People, Processes, and Paradigms. Taylor & Francis.

Murrell AJ, Blake-Beard S, Porter Jr. DM. 2021. The importance of peer mentoring, identity work and holding environments: A study of African American leadership development. International Journal of Environmental Research and Public Health 18(9):4920.

Nadler DA, Tushman ML. 1980. A model for diagnosing organizational behavior. Organizational Dynamics 9(2):35–51.

NASEM [National Academies of Sciences, Engineering, and Medicine]. 2019. The Science of Effective Mentorship in STEMM. Washington, DC: The National Academies Press.

NASEM. 2020. Effective practices for addressing gender disparity in recruitment, advancement, and retention in STEMM. In: Promising Practices for Addressing the Underrepresentation of Women in Science, Engineering, and Medicine: Opening Doors, 91–120. Colwell R, Bear A, Helman A, eds. Washington, DC: The National Academies Press.

Phillips LT, Kreps TA, Chugh D. 2024. Different ally motivations lead to different outcomes: How self-transcendence and self-enhancement values predict effectiveness of self-identified allies. Organizational Behavior and Human Decision Processes 182:104333.

Schenk L, Sentse M, Lenkens M, Nagelhout GE, Engbersen G, Severiens S. 2021. Instrumental mentoring for young adults: A multi-method study. Journal of Adolescent Research 36(4):398–424.

Varty C. 2022. I'll Believe It When I See It: Widespread Use of Organizational Diversity Statements Undermines Perceived Sincerity and Organizational Attraction (dissertation). Schulich School of Business, York University.

Westra E. 2021. Virtue signaling and moral progress. Philosophy & Public Affairs 49(2):156–78.

Wilton LS, Bell AN, Vahradyan M, Kaiser CR. 2020. Show don't tell: Diversity dishonesty harms racial/ethnic minorities at work. Personality and Social Psychology Bulletin 46(8):1171–85.

Yin J. 2024. The role of mentors' paradox mindset on career mentoring: Application of attachment theory. European Journal of Training and Development 48(3/4):407–21.

Methods are presented for strengthening and fully leveraging a flourishing ecosystem of talent.

Endless Talent Is the American Dream:
A Draft Blueprint for Realizing the Full National Potential

Megan Smith, Wanda A. Sigur, and Puneet Ahira

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Towards the very end of World War II, after America had borne witness to its greatest societal mobilization of women and men, young and old, more undeterred by state lines, racial lines, and religious lines, Vannevar Bush penned the report *Science: The Endless Frontier* (1945). Bush, President Roosevelt's trusted counselor and the country's first science advisor, wrote the now-iconic piece in response to all that had happened, and all that still needed to happen. Speaking of the country's vast and yet unrealized shared economic potential, he said:

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> It can be achieved only by releasing the full creative and productive energies of the American people.

Nearly 80 years later, it is worthwhile to take stock of where we have reached in fulfilling this vital pursuit, which underpins not only America's economic viability but its social, cultural, political, and physical viability. When the members of the Academies and their networks of friends and affiliates assess the make-up of their organizations, leadership, partners, and allies, will they find the intergenerational, interracial, and interscholastic richness that has allowed Americans to stand tall and resolved in the face of impossible odds? Given a compelling accumulation of data (Greesonbach 2019) and historic evidence demonstrating higher rates of innovation, productivity, and profitability from diversified teams, what kind of wake-up call will it take to prioritize the obvious?

There is both precedent and process to make disproportionate gains in fully harnessing the endless talent of this country, both native and naturalized, and doing so is of the highest strategic, economic, and political national interest.

The good news is that proven practices and capabilities already exist, ready-made to be scaled and institutionalized, alongside pathways for continued iteration, adaptation, and the development of more. Like the trim tab, seemingly inconsequential changes to approach can radically alter direction, and ultimately the nature of the frontiers discovered. The first task at hand is to share what works (proof points, methods, innovations, collaborations) and get to work. The second task is to ask each other the hard questions for shared consideration and to be relentless in our resolve to help one another.

This article includes references and examples for actions that all organizations can incorporate today (see the "Bolstering Organizational Mechanics" section), and then delves into existing methods for priming, strengthening, and fully leveraging a flourishing ecosystem of talent (see sections covering methods 1–5, e.g., "Method 1. Scout & Scale"). The intent is to demonstrate that there is both precedent and process to make disproportionate gains in fully harnessing the endless talent of this country, both native and naturalized, and that doing so is of the highest strategic, economic, and political national interest.

Bolstering Organizational Mechanics

Several years ago, the US Office of Science and Technology Policy canvassed colleagues across federal agencies, corporate management, employees working within technical industries, and workforce inclusion experts and published an action grid called *Raising the Floor* (Smith and Powers 2016), which presented measures to immediately scale into effect. These diversity, equity, and inclusion (DEI) efforts are not aesthetic attempts to configure a Noah's Ark. They are conceived out of the unrelenting truth that unexpected genius emerges from all quarters. History and science provide continuous empirical proof, particularly at moments when stakes are high. The practices outlined in the grid have been demonstrated to work across organization size and industry domain, yet many are still not widely known or commonplace. A condensed version of *Raising the Floor* has been provided with the permission of the co-authors (figure 1). Spanning four organizational areas—leadership, retention and advancement, hiring pathways, and the talent ecosystem—it includes pragmatic steps to be taken, with suggestions for contextual additions and evolution. *Raising the Floor* is an evolving tool to be kept close at hand for action and iteration by C-suite, managers, strategic/operational leadership, and, where relevant, the board.

Foundational Tenets: Creative Confidence and Widened Apertures

Further in *Science: The Endless Frontier*, Bush describes how the committee advising him on scientific personnel offered the following foundational tenet to guide future planning for the country:

> We think it very important that circumstances be such that there be no ceilings, other than ability itself, to intellectual ambition. We think it very important that every boy and girl shall know that, if (s)he shows that (s)he has what it takes, the sky is the limit.

Creative confidence empowers, activating common sense, critical thinking, eternal optimism, and a widened

		Key Actions	Best Practices	Data to Track
Leadership. *Increase senior and mid-level engagement on inclusive excellence / DEI (diversity, equity, & inclusion)*				
1.1	**Create Concrete Engagement Points**	• Track DEI efforts and outcomes as part of regular meeting agendas, including as weekly executive staff standing item • Schedule regular internal and external engagements including organizational-wide DEI-inclusive events (town halls, all hands, etc.) with senior leadership	• Ensure leadership is engaged with employee resource groups (ERGs) as 'exec sponsors' providing air cover • Hold executive 'listening sessions' where execs / board members hear underrepresented employees' positive & negative workplace experiences	• Number and percentage of diversity-related/included events with senior leadership present. Amount of lift based on the seniority of the leader affiliated with the event (e.g. social media impressions, attendance) • Presence of DEI topics on agendas
1.2	**Upgrade Mentorship by adding Advocacy**	• Counter confirmation bias by scouting mission-critical work led by underrepresented employees • Create guidelines to ensure cross-demographic advocacy	• Share accomplishments and insights with 'skip managers' (an employee's manager's manager) • Secure authorship on joint works • Ensure presenting / speaking roles	• Track sponsorships, incl. progress of employees with advocates vs without • Recognition rate of underrepresented employees (e.g. promotions, speaking, authorship, awards, etc.)
1.3	**Create & Share Accountability Mechanisms**	• Establish, measure, incentivize, and prioritize performance metrics on DEI for all managers and leadership • Share best practices widely and rapidly	• Develop DEI performance strategies, holding managers accountable • Consider success on DEI when evaluating advancement and recognition	• DEI performance over time, team by team, in order to better correlate outcomes with practices • Retire less effective practices
1.4	**Embed inclusive excellence / DEI into high level organizational strategy**	• Relate bias mitigation, diversity, and inclusion goals to organizational mission • Discuss DEI at meetings / town halls, as part of reporting on progress and challenges	• Ensure the individuals championing the DEI strategy include leaders from well- and underrepresented backgrounds • Provide coaching to leaders on how to talk about tough issues related to DEI to improve comfort in leading dialogue	• Degree to which employees feel DEI strategy is clear and effective • Number of organizational / team priorities with DEI as part of stated outcomes, with clarity on connection to business impact

		Key Actions	Best Practices	Data to Track
Retention & Advancement. *Improve the retention and upward mobility of underrepresented talent*				
2.1	**Identify Current Obstacles**	• Conduct a barrier analysis that identifies obstacles for advancement and remedial efforts already underway • Conduct research on organizational culture, policies, and practices and how they influence retention	• Connect with other similar organizations and share findings on what impacts retention for underrepresented groups • Gather, analyze, and share data from exit interviews, promo results, surveys, focus groups to revise policies / approaches	• Promotion rates by demographic • Reasons for leaving by demographic • Mission-critical assignments by demographic • Demographic of managers with highest to lowest retention
2.2	**Analyze & Share Data and Data Practices**	• Be transparent throughout all levels of organization about workforce data • Examine data to determine if 'neutral' policies have unbalanced outcomes	• Ensure workforce data shared includes demographic, seniority, and job function • Review flexible work policies, tenure-based advancement, termination criteria	• Frequency, granularity, and quality of workforce data shared • Number of policies amended and the number of employees impacted
2.3	**Train the Current Workforce**	• Institute DEI training including unconscious bias & managing a diverse workforce training • Equip managers with diverse workforce skills including conflict resolution, flexible work practices, etc.	• Track impact of training on hiring & management of underrepresented talent • Ensure training is not one-off, but coherent, contextual, and empowering • Always incorporate the latest research	• Percentage of workforce engaging in DEI trainings / sharing best practices • Splice data based on seniority, team, etc. to discern patterns of uptake • Solicit feedback by demographic
2.4	**Leverage Professional Development**	• Expand, diversify, and track the effectiveness of mid-level professional development programs	• Ensure several pathways to prof dev (self-elected, manager-nominated, etc.) • Create tailored prof dev, including ERG supported or co-led, solicit feedback	• Utilization rate of prof dev opportunities by demographic • Rates of promotion and attrition rates across participants of each program
2.5	**Institutionalize Formal Feedback**	• Ensure all employees are receiving structured feedback regularly from their managers	• Train managers on providing feedback to individuals who may experience 'imposter syndrome' or 'stereotype threat' • Train managers on soliciting feedback	• Type and frequency of feedback provided by demographic • Percentage of managers engaging in feedback training
2.6	**Support Employee Resource Groups (ERGs)**	• Develop and support spaces where underrepresented talent can find support, friendship, and help • Leverage ERGs as sources of important insight for the organization	• Support and promote ERGs as places where underrepresented talent can come together to support one another • Empower ERGs to share their needs • Give ERGs a budget and an exec sponsor (preferably of another demographic) who attends meetings and is versed in the activities of the ERG	• Participation in ERGs by demographic, executive engagement • Number and types of programs, policies, initiatives, products that emerge from ERGs • Degree to which employees participating in ERGs feel they can be themselves in the workplace

FIGURE 1 Raising the Floor Action Grid (condensed) (*continues on next page*).

Hiring Pathways.
Strengthen pathways for underrepresented talent into your workforce

		Key Actions	Best Practices	Data to Track
3.1	**Conduct Deliberate Outreach**	• Deliberate outreach to diverse *networks*, raise awareness of broad range of existing talent pathways especially those less commonly known • Deliberate outreach to diverse candidates, including from diverse employees • Deliberate outreach to talent across industries and sectors to ensure a greater diversity of backgrounds	• Participate in events + conferences with large concentrations of underrepresented talent and/or that specifically gather them • Hold joint outreach events so candidates can see the full range of career options • Equip highly-networked individuals from underrepresented backgrounds as advocates who can support recruitment • When drafting job descriptions, enumerate skills that are required but could be acquired irrespective of industry	• Number of outreach events held • Demographics of of those attending outreach events • Demographics of applications • Demographics of referrals • Number of diverse influencer advocates recruiting on org's behalf • Number of applicants from adjacent industries or sectors that apply, and their success in the application process
3.2	**Expand Points of Entry**	• Increase slots for paid-internships and other entry-level rotational programs to create a diverse pipeline into and across your workforce • Develop pathways for full-time conversion of high-performing contractors, residents, fellows, etc.	• Ensure deliberate outreach to diverse networks for entry-level programs • Ensure there is a robust strategy for converting interns to full-time hires • Direct non-committed funding towards expanding entry-level programs • Accept short-term placements from other departments to assess interest and fit	• Demographics of interns and conversion to full-time hire by demo. • Demographics of contractors, fellows, etc. and conversion rates by demographics • Difference in benefits between full-time employees and rotational hires
3.3	**Pay Attention to Language**	• Use language that is inclusive and encourages all groups to apply across job announcements, marketing materials, applications for professional development, etc.	• Ensure job descriptions are free from implicit bias (e.g. using gender neutral pronouns and descriptors) • Ensure only skills actually required to do the job are listed as such • Solicit feedback from ERGs on job descriptions and share guidelines based on this, and emerging best practices	• A/B testing of applicants based on differently-worded marketing materials and job descriptions • Number of current job descriptions that follow the guidelines provided by your organization
3.4	**Prioritize Data**	• Collect, analyze and disseminate applicant flow data for all positions in order to inform outreach and identify points of bias in the hiring process	• Look for demographic trends throughout the recruiting funnel and use this data to iterate and develop targeted interventions • Scout for best practice and develop a strategy for how you will collect and store data over time and a plan for how to integrate data throughout hiring process	• Track demographics across the full recruiting funnel including outreach, e.g. background of person reached through marketing, applicants, candidates at each phase of screening, accepted / declined offers.
3.5	**Update Candidate Screening Systems**	• Create repeatable systems for hiring that minimize bias and maximize organizational objectives • Err on the side of passing candidates through vs. cutting in the early stages of the application process	• Be clear what criteria are being used to assess candidates. Integrate rubrics. • Define ambiguous terms like 'culture fit' with specific adjectives and indicators • Interrogate hiring software to ensure automated screens are not creating bias	• Number of candidates who would have failed the previous scheme but who succeed in the current scheme • Rates of 'bad hires' (the number of people let go in a probationary period or in their first year in the organization

Ecosystem.
Build external constituencies of support

		Key Actions	Best Practices	Data to Track
4.1	**Find Allies in the Work**	• Hold a regular symposium on inclusive excellence with community partners, think tanks, universities, nonprofits • Consider collaboration with professional affinity organizations, think tanks, and universities to promote DEI and leverage their help to identify best practices and source diverse talent	• Establish a community of practice with regular meetings (e.g. quarterly) with opportunities for virtual sharing of best practices, challenges and insights • Cross-collaboration can include joint recruitment efforts, symposiums, mid-level talent exchanges, agreeing to host interns / fellows / residents, etc.	• Track demographics of those attending symposiums, and resulting outcomes • Track number of collaborations • Track the number of applicants / hires that result because of collaboration • Track and increase monetary support invested in supporting networks
4.2	**Use Moments of Influence to Further the Work**	• Include criteria on equity and inclusion when evaluating proposals from external grantees, contractors, or partners, consistent with applicable legal provisions • Ensure a diverse group of evaluators when considering proposals from grantees, contractors, suppliers, and collaborators	• Evaluate whether external organizations with which you are aligning have robust bias mitigation and DEI strategies • Request disclosure of DEI strategies in proposal and partnership processes • Consider the full breadth of expertise / experience needed when composing an evaluative panel to ensure broadest participation	• Track workforce data disclosed by grantees, contractors, and collaborators • Track demographic composition of decision-making bodies, monitor their sharing / leveraging of best practices • Measure differences in diversity and quality of decisions made over time

FIGURE 1 Raising the Floor Action Grid (condensed) (*concludes*).

aperture of shared respect and belonging. It is the substrate necessary for co-creation, course correction, invention, and resilience. Each one of us reading these words has been empowered with a *creative confidence* at some point in our lives. In order for American institutions, organizations, companies, and communities to be capable of partaking in the revolutionary change that lies ahead (e.g., across AI, quantum, bioengineering, regenerative agriculture, etc.), the people that exist within them require creative confidence.

There are many pathways to achieve this objective, among them are high-impact ecosystem methods (often overlooked) that accelerate emergent individual and collective genius. These methods are outlined in the following five sections: “Scout and Scale,” “Build Communities of Practice,” “Network the Networks,” “Sprint, Prototype, and Iterate,” and “Circulate Stories and Share Data.” When used together, they dramatically advance progress. Teams in every corner of the country (and across the world) are already using these methods to drive economic growth for all and to contextually address highly complex, generational challenges.

Method 1—Scout and Scale: Make Visible the Doers, and Help Them Accelerate

During an address on jobs at the University of North Dakota in 1963, President John F. Kennedy said, “Things don’t happen, they are made to happen.” And quite often they are made to happen by tenacious, iron-willed individuals with creative confidence who attract strong, well-rounded teams. The entire model of venture capital relies on such teams. VCs don’t make companies; they scout for the individuals and teams already in process and provide fuel to accelerate progress. This method of scout and scale, especially when applied beyond the sole metric of shareholder profit, creates tremendous economic and social impact.

Innovation and experimentation using the open tools available to most of the population on the planet today allow for the breaking of echo chambers and a groundswell of additional talent never before made visible. Yet today, conventional scouting is so often limited to relatively closed networks that circulate the same usual suspects from one venue to the next. A global example of this kind of whole-scale upgrade is the UN Solutions Summit,[1] which ran annually for five years from 2015 to 2019, with the first convening held just one hour after the global ratification of the UN Sustainable Development Goals (SDGs). The UN Non-Governmental Liaison Service (UN NGLS) hosted an open webform inviting the world to share what they were already doing to advance one or more of the SDGs, and then facilitated an independent global committee for selection and curation. More than 800 submissions were received from individuals and teams from over 130 countries, from a mechanical engineer (who also happened to be a princess) from Burkina Faso innovating on solar energy distribution via 3,500 female-run cooperatives in Sub-Saharan Africa to an entrepreneur from the Peruvian jungle extending opportunity by organizing indigenous innovators of all ages to deploy a Floating Fab Lab across the distant tributaries of the Amazon River. The points of light of works already in progress were staggering.

> ***Teams in every corner of the country (and across the world) are already using these methods to drive economic growth for all and to contextually address highly complex, generational challenges.***

With the organizing leadership of the UN NGLS, joined by high-level representatives from the UN, alongside government agencies including the US Office of Science and Technology Policy; the Brazilian Ministry of Science, Technology, and Innovation; the Kenyan Ministry of Information Communications and Technology; the Estonian Ministry of Foreign Affairs; and the Chilean Ministry of Economy, Innovation Division; and the support of the UN Foundation, with contributions from corporate partners, academic partners, and community partners, fourteen teams were given a stage at the UN in the hours immediately after ratification of the SDGs to share their work and solicit help and collaboration. An audience of policymakers; donors; leaders of industry, foundations, and community organizations; academics; researchers; students; designers; and story-

[1] medium.com/@ObamaWhiteHouse/it-takes-a-network-9e7831333906

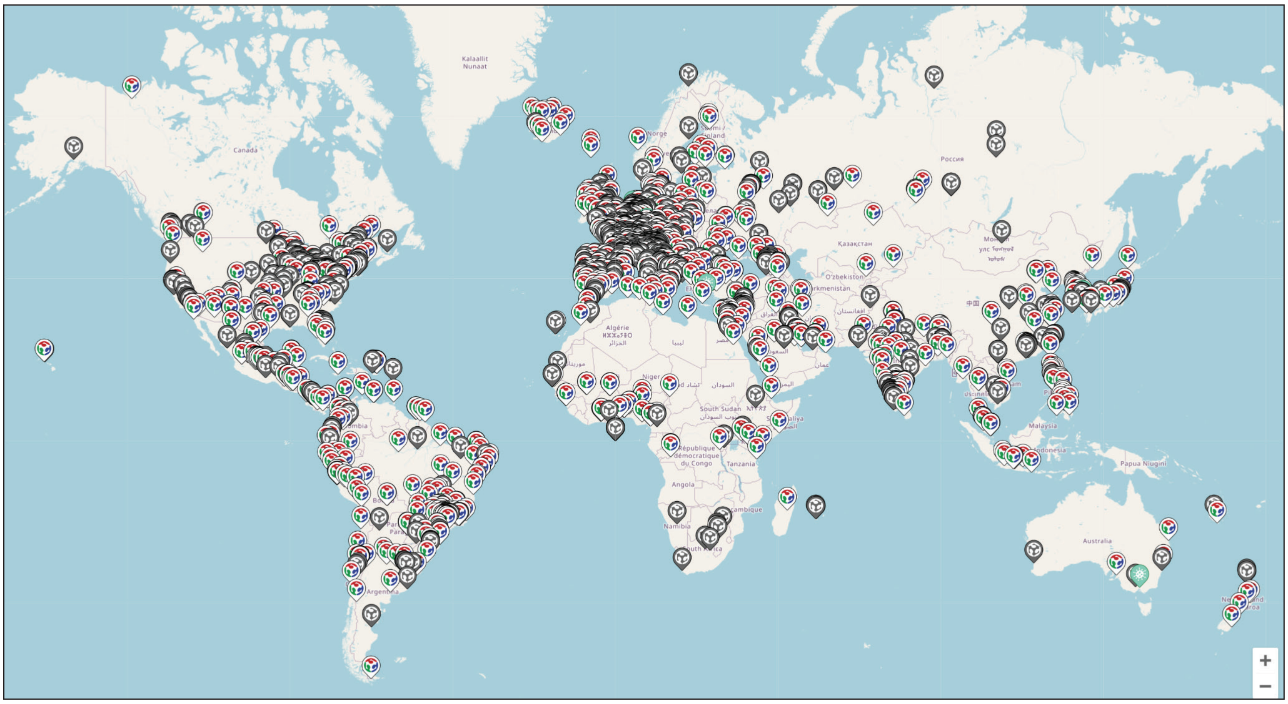

FIGURE 2 Global Fab Lab Network (2024). Map data from Google.

tellers assembled to workshop each solution and provide immediate offers of support, with mechanisms for longer-term engagement and advancement.

Examples like the UN Solutions Summit are plentiful. Inside corporate environments like Google, platforms like Solve for X[2] were convened in order to surface global teams working on "moonshot" scale projects amongst a community of captains of industry who served to connect dots, unblock barriers, and accelerate progress. Solve for X became a formative catalyst for the creation of SOLVE at MIT, which uses similar mechanics but gives greater emphasis to social impact and social entrepreneurship, including the co-creation of the Indigenous Communities Fellowship. Fellowship programs like Vital Voices and the Unreasonable Group, amongst many others, have existed for decades and rely on scout and scale as the main through-line of their organizations. Rise of the Rest is a venture capital model with the thesis that high-growth companies can start and operate anywhere, not just in a few coastal cities. For many years, the Rise of the Rest team visited five American towns during a five-day multi-stop bus crawl, investing ~$500K in local startups by scouting for under-the-radar founders, and dramatically increasing the visibility of a whole ecosystem of local innovation partners.

Method 2—Build Communities of Practice: Placemake (Physically and Digitally)

Truth is still stranger than fiction, especially when open, Wonka-esque spaces are hidden in plain sight. Valuable for everyone, more than 2,531 fabrication labs (figure 2) with tight-knit communities exist today in every far-flung corner of the world, which collectively form the Fab Lab Network,[3] and most people still have no idea such resources are at hand. The Fab Network began from a seed of an idea, when in 2001 the NSF provided funding for an ambitious proposal to create a Center for Bits and Atoms at MIT equipped with one of (almost) every tool (research instruments, manufacturing machines, rapid prototyping, and component processing tools) to make (almost) anything—from a skateboard to quantum dots. Out of this assemblage next emerged the pragmatic course "How to make (almost) anything" as a means to learn how to use the tools that had been amassed. Surpassing all expectations, the course was overenrolled on day one by an order of magnitude, and it continues to be. Students show up from all across campus, not just to do research but because they want to make things. From this initial outburst of interest in *personal* fabrication, alongside a mandate from the NSF to demonstrate broader commu-

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2 blog.google/alphabet/solve-for-x-2014-celebrating-and/

3 https://www.fablabs.io/labs/map

nity impact from the grant, the first open-access Fab Lab anchored within a community (Boston's South End) was conceived. One to two, two to four, four to eight—the number of new Fab Labs spontaneously doubles every year, each lab equipped with machines to make, and also machines that make the machines to make (i.e., one Fab Lab can make the next).

The connectivity of this "community of practice" is its lifeblood. That connectivity has a constant digital pulse that beats via the "Academany,"[4] which includes a version of the original course "How to make (almost) anything," an evolving suite of daily communication and process documentation platforms (e.g., Mattermost, Gitlab, etc.), and distributed co-creation tools for impromptu, urgent problem-solving, as happened globally throughout the lockdowns during the COVID-19 pandemic. The physical placemaking of the labs, from small towns with a sparse population of a few hundred to the most dense metropoles on the planet, has helped to catalyze creative confidence warmly, openly, and extemporaneously. Every year, the community meets on a different continent for Fabx[5] (e.g., Pune, India — Fab5; Shenzhen, China — Fab12; Montreal, Canada — Fab21), a weeklong gathering of community building, learning, sharing, and co-creating along a specific theme (2024's theme, convened earlier this summer in Puebla, Mexico, was "Fabricating Equity"). The Fab Lab community is possibly one of the most economically, socially, culturally, and scholastically diversified communities of practice in existence today, with a clear and deep focus on access and relevance.

And there are so many more communities of practice that are addressing critical needs in geographies where resources may otherwise be scarce, serving populations ranging from kids in pre-kindergarten to the eldest elderly. In Memphis, Tennessee, and Water Valley, Mississippi, CodeCrew and base camp[6] provide an on-ramp for underrepresented talent to learn hands-on real-world technologies, including app development and software engineering, through various programs, some entirely free. Of the 800 K–12 students CodeCrew works with every week, about 92%[7] are African American and LatinX. These kinds of communities of practice are coming together above the local grocery store to gain mastery together, sharing their successes at city-wide BBQs to inspire curiosity, and resurrecting the tried-and-true methods of artisan guildcraft. They exist everywhere on the planet, from the 12 Tech Meetups happening in Boise, Idaho, this month to the 81,000 Women Techmakers in 193 countries supporting each other as advocates and mentors.

Method 3—Network the Networks: Invite and Advance Cross-Fluency

From President Washington's Army Corp of Engineers to modern-day IT and CIO groups to world-class STEM experts leading national programs related to energy, space, defense, and health, nations around the world have always recognized the need for technical talent inside government. Yet this technical bench has often advanced in silos and lacked full integration within the most senior government leadership. In 2009, a newly commissioned role of US chief technology officer was established and empowered with the mandate to harness the power of data, technology, and innovation on behalf of (and working in collaboration with) the American people. Following the catalytic 2013 disaster of the healthcare.gov launch, awareness of this urgent need grew in both the government and commercial tech communities, which helped the US CTO with rapidly expanding the technical talent pipeline into government—recruiting senior leaders, some of whom had helped to build the largest tech companies in America (and the world), to come and serve one- to two-year tours of duty. They were paired shoulder to shoulder with a cadre of dedicated bureaucracy busters and, together, given directives to begin to overhaul the government's digital infrastructure. From the president to his chief of staff to his cabinet, these newest tech recruits were supplied with air cover, agency colleagues, and working space inside two newly established units: the Tech Transformation Services (within the General Services Administration), notably including Presidential Innovation Fellows and 18F, and the United States Digital Service (within the Office of Management and Budget), aligned and embedded across agencies, and empowered to grow agency-based technical capacity. Headlines in the media described a mass exodus of top-tier technical talent flocking east, with the tongue-in-cheek reference "Silicon Valley goes to Washington." Engineers, developers, data scientists, designers, and so many more answered the call to dig deep alongside expert civil servant colleagues and solve critical service delivery challenges, including across veteran affairs, immigration and border control, social security, and healthcare. Others

[4] https://academany.org/

[5] fabevent.org/

[6] basecampcodingacademy.org/

[7] www.code-crew.org/about

were embedded within senior leadership to upgrade capabilities and processes as part of the highest-level national security and economic security efforts. A kind of TQ (tech quotient) was added into meeting rooms across all aspects of government, threading technical fluency into the mix of cross-functional strategy, planning, operations, and decision-making.

Tens of billions of dollars lie waiting in dusty budgets, ripe for better utilization. Collaborative tools and techniques, networks with enabling environments, and scaling factors with the elasticity to adapt over context and time have already been tried, tested, and proven.

Importantly, the gains in fluency also ran the other way. Tech leaders, heralded as the authority in their respective fields, were suddenly confronted with new problem sets offering a dimensionality they had previously never considered. Public service became a real career option for advancing the state of the art. From inception through today, the urgent and vital work of the Office of Science and Technology Policy (est. 1976), the Tech Transformation Services (est. 2014), and the United States Digital Service (est. 2014) continues uninterrupted, and has since expanded into additional teams including Tech Congress (est. 2016), the Census Open Innovation Labs (est. 2016), and the US Digital Corp (est. 2021), amongst others. The US government is not unique in this respect, leading amongst some countries yet losing competitive advantage compared with others where cross-fluency integrations are elevated and prioritized as a linchpin to the national interest. The advantages gained are applicable to all organizations: commercial, philanthropic, academic, civil society, and informal and formal associations.

Today, in high schools across America, a networking of networks is also gaining critical mass. Students deeply inspired by STEM, who otherwise might not run for or be elected as class president, have invented a new role for themselves alongside student government bodies—chief science officers (CSOs). This network of CSOs, who fly under the banner of "don't just hope it happens, make it happen," are charged with the mission of evangelizing STEM opportunities with their classmates and collaborating to make positive impact across their communities using STEM. Today, more than 1,500[8] elected CSOs from parts of rural Alabama and Arizona to metropolitan districts in Michigan and Pennsylvania are weaving pathways between their high school peers and administrators, locally based science organizations, regional cabinets (sometimes including local and state elected representatives), and a national network of STEM advocates.

Method 4—Sprint, Prototype, and Iterate: Begin as a Way to Begin

No amount of conjecture and postulation can offer the practical insight of context-driven experimentation and application. And yet in organizations across the country, committees and consultants are convened to offer singular studies at high opportunity costs, which frequently result in further admiration of the problem. Decades have passed in this manner, with often very little to show by way of meaningful outcomes. One fail-proof method to begin, is to begin. Using all the methods described above, it is possible to scout for talent across adjacent communities of practice and network them together in the form of a "sprint," a concentrated burst of discovery, concept design, and collaborative experimentation that often results in the beginning of some form of multi-disciplinary prototype (e.g., a template, tool, early software, and/or hardware) that can be tested in the real world for further open development and iteration. As preeminent scientist Ellen Swallow Richards (Wylie 2005) advocated, some conclusions can only be caught, not taught. Sprints can take many guises: data jams, data paloozas, hackathons, codefests, editathons, fix-it-days; whatever the name, the intent and bias for action are the same.

This type of approach has been used to bring energy and creativity to long-standing evocative challenges like the gender pay gap (e.g., Hack the Pay Gap) and the use of police force (e.g., the Police Data Initiative). In the first instance, Presidential Innovation Fellows at the US

[8] chiefscienceofficers.org/program/

Department of Commerce, working with newly released census datasets on income, went on a six-month roadshow across the country, convened 350+ data scientists across 15 markets, and hosted a public Slack channel for ongoing examination of data related to motherhood penalties, hiring biases, and the economic impact of wage discrimination. This was followed by 12 weeks of intensive prototyping by 45 individuals from around the country organized into seven teams, and culminated in the first-ever White House Pay Gap Demo Day, with the secretary of commerce testing product prototypes ranging from a VR salary negotiation simulator to a personalized pay gap calculator—all of which was covered in the *Wall Street Journal* (Morath 2016). The gains may seem incremental, but it is the steady beat of action that advances shared knowledge and the probability of righting a generations-long struggle for the benefit of everyone. A Moody's Analytics study (Holland and Ell 2023) projected a gain of ~$7 trillion per year to the global economy by closing the gender pay gap in OECD countries; in the United States this figure is estimated (Shaw and Mariano 2021) to be a ~$541 billion per year gain to the economy. These are not conceptual gains but fully realizable opportunities for substantial economic growth.

Method 5—Circulate Stories and Share Data: Inspire Creative Confidence

Taraji P. Henson, the award-winning actress who plays NASA mathematician Katherine Johnson in the blockbuster Hollywood movie *Hidden Figures,* gives an apt glimpse into the film's impact. At the Toronto Film Festival, prior to its release, she said between tears, "I'm a girl from the hood. I didn't grow up with much, so all I had was dreams and hope. The reason why this is so overwhelming is because when you come from a place where you have no dreams, no hope, and all you see is that people that look like you don't belong or they have no place in society ... If I had known about these women coming up, maybe I would have aspired to be a rocket scientist." The force of the media has never been more potent than it is today. It has the power to reinforce and propagate debilitating bias, stereotypes, and prejudice, and it has the power to break all three.

Katherine Johnson was an unnoticed, elderly African American woman in her 90s in 2014. Very few people in the country, let alone the world, knew that she existed, and even fewer that she was an invaluable member of NASA's Langley Space Task Group and responsible for calculating and verifying the trajectories that took the first Americans to the moon and back. By the time *Hidden Figures* was released, Katherine had received the Presidential Medal of Freedom and had become the centerpiece of a book (a #1 *New York Times* bestseller) and a film (the highest grossing Best Picture nominee at the 89th Academy Awards), read and seen by hundreds of millions of people, young and old, all over the world. Katherine's story is one of an untold number of untold histories—historic and current. It takes concerted, collective effort to rewire hearts and minds and reveal a long-deferred, more accurate past in order to steer towards a more gracious future. Often, that means mining through vast amounts of data and confronting harsh realities that may be entirely unintentional, for example, as demonstrated by the "Film Dialogue Dataset" (Anderson and Daniels 2016) published as a visual essay for *The Pudding*, where across 2,000 popular films the number of lines of each role is broken down by gender and age (figure 3); or by "GD-IQ" (Paul 2017), a tool developed by the Geena Davis Institute and USC Viterbi School of Engineering that uses signal processing and machine learning to objectively process the details of movies, for example, detecting gender by facial recognition, tracking on-screen time, and analyzing linguistics/word choice.

Spurred by the confluence of efforts to circulate better stories through better tools that help to make sense of underlying data, the Association of National Advertisers launched the SeeHer movement with a mission to "increase the representation and accurate portrayal of all women and girls in marketing, media, and entertainment to reflect culture and transform society." The effort includes the Gender Equality Measure, a data-driven protocol for identifying gender bias in media, which has now become a global industry standard for measuring and mitigating gender bias in ads and other programming as a means to increase effectiveness and boost ROI. Given that women control nearly $32 trillion in consumer spending,[9] taking the time to help each other to get the story right makes moral and financial sense. To date, GEM has been used across 7,250 brands valued in aggregate at $70B+ in ad spend.

The vast archive of untold stories, historic and contemporary, extends far beyond gender. It includes race, class, creed, geography, trade, and aptitude and covers both tragic and heroic experiences of everyday Americans that have gone unnoticed for far too long. It includes stories of unexpected allies with the courage, tenacity, and generosity to expect more. Americans won't grasp the full

[9] www.seeher.com/what-is-gem/our-impact/

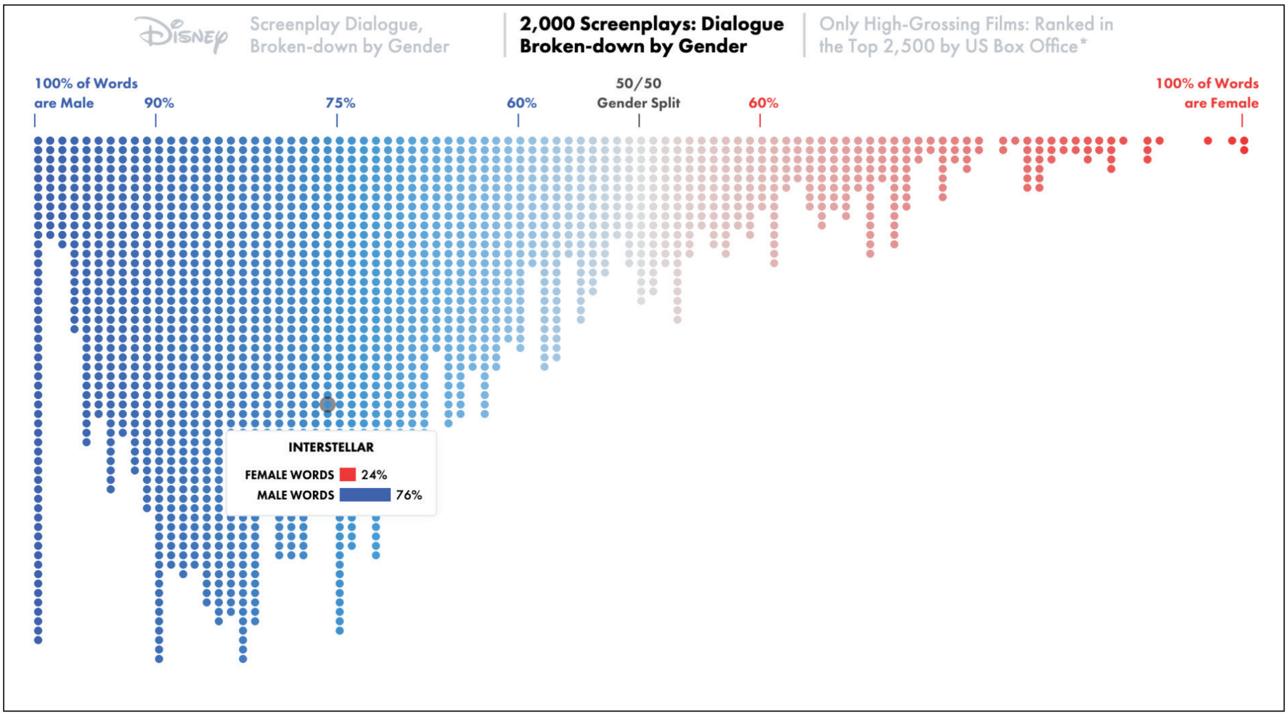


FIGURE 3 Film Dialogue Dataset. Source: *The Pudding*.

richness and context of their country until they see with honest eyes what "home" looks like for every American. The state of the union must be known in human terms before it can be meaningfully advanced.

A Draft Blueprint to Advance and Evolve

America's greatest strategic asset has been and will always be its talent, both latent and realized. In today's grand global arms race for complexity, there is a growing, tacit resignation to the idea that humans will be pushed further and further out of the loop, disintermediated from the detail, and distanced from decision-making. This narrative is both naive and dangerous. Only where there is space for a *plurality* of approach can real resilience take hold and flourish. Every American deserves to be empowered with a critical understanding of how the world works today—from atoms to bits to nodes to quanta—so they have the means and opportunities to bring their insights, vision, and experience to bear and participate in what comes next. To settle for anything else would be to squander a national inheritance.

Stuck up on the wide bricks of a third-grade classroom is a wall-to-wall poster that reads in bright colored letters: *In effort, there is joy*. To unleash the full creative and productive energies of the 342 million people alive in America today would be the greatest undertaking this country (or any) has ever made. Perhaps more than any other concerted effort, it has the power to vastly transform industry, commerce, trade, science, technology, the arts, politics, culture, health, and education in one fell swoop. Amongst the organizations represented by the members of the Academies, we have the means, the methods, and the money to direct towards this bigger work—complex problem-solving through diversified inclusion. Tens of billions of dollars lie waiting in dusty budgets, ripe for better utilization. Collaborative tools and techniques, networks with enabling environments, and scaling factors with the elasticity to adapt over context and time have already been tried, tested, and proven. There is an urgency to the present moment that demands bold and decisive effort. Endless talent exists. There is actually nothing standing in the way of success except the will to get started on the opportunities shared here (and elsewhere) and the collective will to scale by helping others do the same.

References

Anderson H, Daniels M. 2016. Film dialogue. The Pudding, April.

Bush V. 1945. Science: The Endless Frontier. National Science Foundation. Alexandria, Virginia. Online at www.nsf.gov/about/history/EndlessFrontier_w.pdf.

Greesonbach S. 2019. Diversity and inclusion research round-up: Top studies you need to know. Glassdoor, Feb 22.

Holland D, Ell K. 2023. Close the Gender Gap to Unlock Productivity Gains. Moody's Analytics.

Morath E. 2016. Narrow the gender pay gap? There are apps for that. The Wall Street Journal, July 19.

Paul B. 2017. Shri Narayanan teams up with Geena Davis to combat gender bias in Hollywood. Viterbi Magazine, spring.

Smith M, Powers LW. 2016. Raising the floor: Sharing what works in workplace diversity, equity, and inclusion. The White House, Nov 28. Online at obamawhitehouse.archives.gov/blog/2016/11/28/raising-floor-sharing-what-works-workplace-diversity-equity-and-inclusion

Shaw E, Mariano H. 2021. Narrow the gender pay gap, reduce poverty for families: The economic impact of equal pay by state. IWPR #R653. Institute for Women's Policy Research. Washington, DC.

Wylie F. 2005. Ellen Swallow Richards: The first oekologist. Jamaica Plain Historical Society, April 14.

An Interview with . . .

Arlene Harris,
president and co-founder, Dyna LLC

RONALD LATANISION (RML): Today we're delighted to welcome Arlene Harris. Arlene, you're sometimes described as the First Lady of Wireless; you're in the Wireless Hall of Fame, and you began your career at age 12, operating the switchboard in your dad's shop. So, Arlene, let's begin with that early stage of your career. I think our readers would be interested in hearing how that began.

ARLENE HARRIS: Well, my dad was an electrician, and I actually started working when I was barely big enough to sit up in a chair and tap on the keyboard of a calculator. In those days, the calculators had dozens of keys, and my job as a six- or seven-year-old was to add up columns in my mother's ledger while she was keeping books for my dad's electrical business.

He went on to put communications, two-way radios, in his trucks so that he could communicate with his workmen while they were out on the job, keep track of what they needed, and so on. When I was 12 years old, he recruited me to fill a shift on the switchboard. This was a mobile telephone switchboard. That's how I got roped into becoming a communications person.

It turns out that, back then, when I was 12 in the '60s, I sat on the switchboard overnight. That was my shift. And in order to connect mobile telephone calls back then you had to connect the calls with cords, and you had a speaker up above so you could listen to the phone calls, and you could hear both sides of those phone calls. Separately, you had a gadget called a calculagraph, and as soon as a phone call that you made for a mobile telephone was answered, you would start the clock. In those days in the telephone business, this was called toll ticketing.

When the call was over—because you were listening, you knew it was over—they would say "goodbye," or "over and out" or something clever like that. Then you stopped the clock. Each ticket represented the time of the call and the respective mobile telephone so it could be billed.

RML: Your dad must have been way ahead of his time, though. This was really unusual, was it not?

MRS. HARRIS: At first he tried to do what he was doing with a ham radio and couldn't do it, according to the Federal Communications Commission (FCC) rules. Ham radio was a hobbyist and consumer kind of thing, where people who had ham radios would talk to each other. But he got a license from the FCC to provide commercial service. He had one license, and so his ace in the hole, which really made him a visionary, was that in the Los Angeles Basin, where this service was provided, he went up to the highest mountain tops, three of them, to put up antennas to provide coverage for that one channel. It was a duplexed channel license. You would talk on one channel and listen on the other one. And some of the radios back then were still push-to-talk, what's called simplex.

When he went up to those mountain tops, he was actually able to cover the San Fernando Valley, which is a big area in Los Angeles. And the other antenna site was up over Orange County, and it looked into the inland empire of Riverside, San Bernadino, part way to Palm

Springs. Unlike a lot of those who ended up being his competitors, he was serving a huge area.

Now mind you, and this is the key, only one conversation could go on during that time. So when a mobile came on the air and you acknowledged them, they used that spectrum for the entire coverage area as long as their call was up. And it wasn't automated. It was connected by those cords and the operator. That was me.

The other interesting part of my work was that, because I worked graveyard shifts and overnight, I heard fascinating customers. Our business was in South Central LA. It was probably a little before things got so bad with guns and drugs and so on. But it was still a very rough area. We had customers who came in from that area who had business that they were conducting. I could hear their phone calls, so I kind of knew what their businesses were. We had celebrities. And we had tow truck drivers that were picking up big truck rigs that had broken down off the freeways and that sort of thing. From the time I was 12 until I left high school, I was listening to the real-world talk about people's businesses, about what they did, about how they solved problems, about cheating on their wives—excuse me, but they did—or their husbands. I was listening to celebrities talk. I had a real education before soap operas were really popular and before social media.

RML: You were very young. You were in middle school at that point, right?

MRS. HARRIS: I was in junior high and high school during that time.

RML: But that really made a huge impression on you it appears, because it shaped your whole life, didn't it?

MRS. HARRIS: Back in the '60s when I was growing up, there were so many things going on. The war in Vietnam had started. When I got out of high school, I went to Honolulu and was with the airlines shipping troops to Vietnam. That was heart wrenching.

There were other great things. We landed on the moon. A few years later in the early '70s, Marty (Martin Cooper), my future husband (unknown to me then), made his first phone call on a cellular phone. During the '60s and '70s, there were enormous disruptions, challenges, and conquests going on. Besides having a little bit more street smarts than my contemporaries had, I had a perspective from that time of great turmoil.

KYLE GIPSON (KG): Your experience working as a child are both impressive—for a 12-year-old to be doing that kind of work—and also super interesting in terms of the window your work offered you into the world. It seems that your interest in telecommunications goes back to the very beginning. I'm wondering if you could speak a little bit about how the environment you grew up in informed what you went on to do, specifically your entrepreneurial endeavors. How did the environment you grew up in spark your entrepreneurial spirit?

MRS. HARRIS: My father was a true entrepreneur. He had no formal training. But he saw opportunities and how to do things right, or do them with long-range thinking, which obviously helps you as an entrepreneur.

> ***In everything that I do, it's about acknowledging a problem and deciding to focus on solving it. It's as simple as that.***

I didn't have kids when I was young, so I didn't get distracted, not that I planned it that way. That's just how it happened. I was able to go through my career, starting with the most important part in my technical career foundation, working a few years with the airlines. I was working for the airlines during their scale up for wide-bodied airplanes. That one development of a bigger airplane caused disruption across the entire airline industry. I was, for a time, right in the middle of that. We had to scale up the airports. We had to scale up the reservations office. We had to put different kinds of facilities for moving baggage and checking people in at the airports. It was a scale up of the entire previous experience of traveling. And what scaling up meant was automation. So I learned about automation in the late '60s.

If you can imagine this—when I lived in Honolulu and my roommate was in LA on temporary duty—we were sending messages back and forth by computer by creating records on the reservation systems for six months out and then using the remarks section to talk to each other. That was a precursor to email. We had a dialogue going every day: Could you pick up my dry cleaning? Or, I think I'm going to come back tomorrow. Or, I'll be on this flight, can you pick me up? We were having that kind of dialogue by using a workaround, as engineers would say, to communicate with each other. Those things were made available because of connectivity.

All of the work that I did when I was with the airlines was organizational. I was doing user interface and experience work to get data into a format that reservations, ticketing, and all of the people on the computer system could use to find out things about what was going on in the rest of the network. There's a long list of the schedule-related things that I worked on, including reserving space for pets on airplanes and reporting snow conditions at ski resorts, the meals that were being served on flights from LA to Honolulu, and the fares between here and there. We also did testing for the new automated ticketing programs that were created to support the wide-bodied airplanes, because you couldn't bring 300 people into the airport and only have half of them ticketed and get the plane off on time.

I would see what the consumers were seeing, and I'd be frustrated with implementations that didn't take into account the needs of whole segments of our society.

RML: You know, Arlene, what I find really amazing about all of this is that you've learned all of the skills that you are talking about on the job. You did not go to college, is that right?

MRS. HARRIS: Right.

RML: So you were self-taught? How did you become so skilled that you could make the airline changes that you're describing?

MRS. HARRIS: You have to remember that this was the late '60s. Nobody was trained to do these things. There were also very few companies building automation equipment. DEC was stepping in. I think HP was too. IBM was into it because they built all the big airline systems. And IBM built a good deal of what was then used in the government. The government and the airlines were the biggest users of computers. There were no servers like we have now. The computers were huge, not what we think of today. And there were no personal computers. In fact, "computer" was a word that people only had a vague idea of back in the late '60s and early '70s. So getting trained to do the work I did and the work that all of my colleagues did, including some of the people who were in the tech area keeping our reservations and systems running, was all OJT, on the job training. You learned by osmosis. I started doing teletype. I pushed Hollerith cards into a crunching machine to adjust seat inventories for Air Canada, and all of this was well before anybody even knew what the potential of computers was.

RML: Did you make a conscious decision not to go to college? Could you see a path forward without having to go to college? Did that enter your mind as you were doing all this?

MRS. HARRIS: The interesting thing is that I didn't make a conscious decision not to go to college. I was never college material. Not because I wasn't smart and not because I couldn't solve problems and do things. But I couldn't read well. I couldn't read appropriately to be in a college program. During grammar school I was always in remedial reading. By the time I got to the seventh grade, that's about the fastest reading and comprehension that I could do. Even today, when I read, my comprehension and my ability to read come from my being able to see words and say them in my head to understand what they mean. All throughout school I never got a diagnosis of reading disorder. So I just avoided any classes that required lots of reading.

The other thing is that I kind of had a misspent youth. I got very interested in cars, and I was very involved in racing my car. I had a car because my dad paid me $1.05 an hour when I started working on the switchboard. By the time I was 15, I bought my own car. And it was a good thing I did because my folks would have to drive me to work. When I got my car they didn't have to drive me to work anymore.

In my neighborhood, where my family's business was, it was very rough, so I had to carry a gun. I carried a gun under the seat of my car. Not that I ever used it. I had a little bit of shooting training but it was one of those things that's like, don't mess with me. And I learned how to drive defensively in my neighborhood, especially at midnight when there was a lot going on.

RML: Your beginnings are truly remarkable.

MRS. HARRIS: It's a little different than the classic "junior high, high school, college, career." I had a different experience.

RML: But you've made such a huge difference, not only technologically but also in the lives of many people. You seem to focus your attention on helping people. I look at the Jitterbug phone, for example. How did that come about? What inspired you to create the Jitterbug?

MRS. HARRIS: In everything that I do, it's about acknowledging a problem and deciding to focus on solving it. It's as simple as that.

I had friends who were working on creating a one-button safety phone, just for older people. My friends failed because they couldn't get financed. But in any case, this problem was something that was introduced to me. It wasn't anything I saw.

Then the thing that really got my juices flowing was that my parents had problems using cell phones. Here's my dad, who ran this big mobile telephone network in Los Angeles, and he couldn't use a cellular phone at the time. This made the problem personal; I was hoping to make something for my parents. They lived out in the country. They would drive their car along the dark highway and not have any communications, and by then I thought, this is just not right.

So I worked on solving that problem. And there were a lot of speed bumps that I ran into as I was getting going, including financing for me as well. We had to figure out how to get on the networks, and the politics at the networks would not allow us on. We figured out a workaround, and it was a very clever workaround. I worked with some very clever guys. We talked about how we were going to do this, probably driven by their insights more than mine. But the key was that if you were to get on the network the way we were proposing to get on, the carriers could just cut you off. And of course, it's very risky to get consumers into a service with the risk getting turned off.

I guess because of what I lived through, I'd never been risk averse. I decided: We're going to do this, and if the carriers try to cut us off, I am going to make a very big stink about it at the FCC (where they got their licenses). So we went ahead and did it, and ultimately we were able to get financing and really roll out the Jitterbug program.

RML: Why did you call it the Jitterbug? What was the origin of that name?

MRS. HARRIS: We had had a previous service called SOS that was primarily a safety-oriented service for seniors. We did have college kids use them when they drove long distances to school, but the primary adopters were seniors. We got into a partnership with Samsung. Marty helped me do that. We knew that seniors were our primary target customers. And the issue was that we needed to pick a brand that would be meaningful to them, so we made a list of the characteristics that we wanted in the name of our product. It turned out that in the cellular business there weren't many good names left by the time we named Jitterbug. But Jitterbug had energy and seniors' recognition and we were able to brand it and get our trademark and our service mark. That's how the name came about.

The fact that we've got so many choices makes what we do very confusing.

The Jitterbug is a flip phone with big buttons and so on. Later on in the company, when I wasn't involved in making decisions, they brought out a smart phone named Jitterbug 2. Had I been in a place to decide how to name it, it would have been named Rock and Roll. Not Jitterbug 2. Because it's a different market serving the new older people, not the older, older people.

KG: I love the name Jitterbug and also the idea of naming a smart phone Rock and Roll. I'd like to zoom out a little bit and go back to Ron's comment that you have been described as a serial entrepreneur, given that you've been influential across a number of different areas over the course of your career. I'm wondering if you could, taking a bird's eye view of your career, say a little bit about what you consider to be the throughline. Is there one thing that you've been working on or towards over the course of your entire career?

MRS. HARRIS: Marty and I have been approached for years about different opportunities that people want our help with, or they want to be advised or want to get investment or some help from us in one way or another. Unless it's solving a real problem, we're not interested. Most of the things that I do are rethinking solutions to old problems. Or taking something and combining it in a different way to come out with a fresh solution that others were either unwilling to do or just never thought about doing.

I have a lot of systems training going back to the early '70s. I had to learn systems that my guys were building. I had to sit with them and learn how they worked. I used to be able to think about the mobile and wireless networks and know exactly what was going on. That's not the case anymore. I'm yesterday's expert. But what I do know is that it doesn't take fundamental research on and development of new things to find ways to make life better and solve problems for people who really need solutions today. So that's kind of been a thread in the things that I thought about doing. It has always been problem-solving. Let's figure out how to fix this.

I guess the other thing is that I've had careers in both fixing problems for industry and for consumers. I fixed problems for industry when I was in the billing and customer relationship management systems, the roaming systems, which I was very much involved with designing. So those things are necessary to make services work. And then there's what is necessary to make consumers enjoy what these systems can deliver. The delivery part is what I focused on later in my career. I would see what the consumers were seeing, and I'd be frustrated with implementations that didn't take into account the needs of whole segments of our society.

Today, the problem, as I see it, is that technology has advanced so much, the adoption by young kids has become pervasive, and we've allowed the technology community to consolidate their power over all of us.

Today, I'm very focused on things like privacy, specifically data privacy. We funded a program called the Internet Safety Lab. And I'm still working on trying to restart a company that I spun up and then had to spin down during the pandemic. So that's another effort. With that effort, we're trying to solve problems for families who have loads of tangible media, all of their old photographs and papers and so on, that really need to be digitized. We want to make that easy and reliable for them. We started that business but we couldn't test our products during the pandemic. I'm hopeful to start it back up again. But again, it's for families. Now, industry is not my focus.

RML: Is what you just described an outgrowth of Dyna, the startup that you and Marty initiated, and the incubator phenomenon that you are interested in?

MRS. HARRIS: We did start it at Dyna, which is just our business anchor. It's an LLC and we've done consulting from it. We've started businesses from there. We've been involved with other companies. Dyna is our home base. We have been involved in starting and helping companies from that home base.

RML: That's what I was wondering. So you actually do provide an incubator for startup companies that come to you with requests for help. Is that right?

MS. HARRIS: Well, we don't finance others within Dyna. The projects that we've funded in Dyna are primarily the things that are our ideas. And when we help folks who come to us, typically we consult with them from our Dyna entity. It's just a way to separate our business life from our personal life.

RML: To shift gears a little, in an interview that I read you pointed out that, for a long time, people could not see the benefits of wireless technologies, and, in fact, some people looked at the technology as being more of a leash than a social benefit. Do you still feel that way? When you look at, for example, the influence that cell phones have had on kids and so on, what do you think about that? Are the social benefits of cell phones still there, or have they been curtailed in some respects by the harm cell phones are doing to kids?

MRS. HARRIS: Well, the issue of technology being a leash is no longer an issue. It used to be that if you had a cell phone or if you had a beeper, before cell phones, a lot of people felt like they were being leashed because others could find them—they would have to react. Today, the problem, as I see it, is that technology has advanced so much, the adoption by young kids has become pervasive, and we've allowed the technology community to consolidate their power over all of us. When I say we've allowed it, that's what's happened. And, consequently, things that we used to think were sacrosanct aren't anymore.

For example, with social media, before the advent of mobile telephony and computer services, if you were a broadcaster, the FCC had rules about how many markets you could be in. The FCC kept media people from having a monopoly influence over people's minds by putting up radio and newspapers in every market. Well, then you've got Apple and Google. Apple, Google, and a few others are now the dominant access to global markets. They don't have any restrictions on what gets published. Those who distribute information on the internet are not under any real guidelines about what they can do or where they can do it. And so they've got effectively a global footprint, not just seven or eight markets that a publisher could have in the United States 20 to 30 years ago, but an entire world market.

That has changed how we should be thinking about what these systems should do and how they should behave. By the way, I've never been a parent, but Marty and I have some grandchildren. And the fact is that parents have such a hard time managing the influences on their children today. When we were kids we'd go out on our bicycle and maybe get in trouble. But now, kids can sit in their bedrooms at night and get in trouble.

My hope is that there will come a layer in the network that, if I have a device, this layer will be there to protect what goes on and how my device serves me, and the rest of the world has to go through my filter, and parents would have the ability to manage that filter for their kids. Hopefully we will get to the level where we have our own personal AIs that are aware that someone is underage and that there needs to be some supervision, and that the things that come into your view are then curated by your personal AI.

It's a very difficult thing to do. What I'm investigating now is whether our operating system people and our chip makers are needed to do what is needed to get to that level—essentially, splitting up what comes through cell phones into curated and protected services.

RML: I think that's a very interesting idea. What prompted my question was the recent interest on the part of the US Senate and Congress in terms of banning TikTok, and that's partly to do with the Chinese government's influence but also the impact TikTok has on young kids everywhere. Your approach might be a far better one.

MRS. HARRIS: A lot of people have said that we are no longer in control, and we never will be again. There's been a transformation in industry, and we've all been sucked up into that. They've done wonderful innovative things for their companies and us while in recent years invaded our privacy and unleashed terrible influences without concern for the unintended consequences, and here we are.

The thing is that we've been involved with and concerned about data privacy for a long time. We've got a lot of people saying privacy is gone and we'll never get it back. Well, my feeling is that if we did the right thing to get privacy back, it would only take a few years, and information that was taken from us five years ago would be stale. So we could just stop that flow and make sure that going forward we have good guardrails, including on what AI is going to do for us and to us.

RML: There's so much concern about AI in the context of potential negative effects on our society but what you're suggesting is actually a very useful approach.

MRS. HARRIS: Well, it's a thought. The networks have become so complex in the way they interface and all of the protocol—everything that has to work together just to make products. It's almost impossible today to make anything that will get any reasonable adoption or have a business plan where you can raise money. It's almost impossible to do that without having to deal with these big monsters. Because everybody's carrying an Android or an Apple phone, you're kind of stuck. If you're building software for people who carry these devices, you're just going to have to put up with it until there're ways to do things differently.

Problem-solving by going on a bench and making something or coding something for a system as an individual isn't going to be enough for the big problems that we've created. Our systems have simply become too complicated.

KG: One thing that I am picking up on here in our conversation, and also in thinking about all of your accomplishments, is your ability to think from the perspective of consumers. You have an interest in user friendliness, protecting people's privacy, and solving problems for consumers. How would you assess the state of user friendliness or accessibility as far as technology goes today?

MRS. HARRIS: Some people have impairments, let's say. They're not necessarily old. They have impairments. Unless devices are made purposeful and branded for them, if you go to the mainstream mass market, you will not find user experiences that work for them. Period.

It's just the way it is. So you have to almost brand for that market and focus on a problem to get it solved.

Think about the fact that we've got all of these platforms that we work on. I have five big platforms that I work on and then other software that I work on when I'm involved with a project—say a nonprofit. I've got to adopt their selection of tools to be able to look at their reports. The fact that we've got so many choices makes what we do very confusing.

What I believe has been needed in the market are stores that are curated for a purpose. And we need to be able to give whole segments of the community ways to get at things that are purposely made for a specific market. Now, that means you do have to adopt some of the demographic sort of standards or things that people believe are pretty typical of a particular market. It doesn't mean you can't go to other stores. For example, you could have a curated app market for seniors, people who are 80 plus, or for kids, who are under 10. It's not perfect but it's possible to have things broken down where there are other people that are actually doing the tests and looking at how consumers behave and saying that this product should not be marketed to these people.

In fact, I think things have gotten worse. All of these systems that don't play nice with each other because they're trying to own the customers, their contacts, their photos, or this or that. I really dislike that a lot.

RML: I'm just curious, you really have a remarkable history and sense of perspective. Do you share that with other young people? Do you meet with young people and talk about these things?

MRS. HARRIS: I do. I've had many interviews much like this. Yours has been fun. Every time I do this it makes me think of things I haven't thought about. Sometimes people ask me to tell them some of the things that I would advise other people. There's so much distraction in trying to do things today that it makes it hard for people to focus. And so you have to pick which thing you're going to do. And in my case, today I'm not nearly as busy as I was because I spun down my startup two years ago, and I'm in the process of figuring out how to spin it back up so that's a work in progress.

But you also have other things people ask about—you know, family issues when you're an entrepreneur. I can say that my mom, when I was growing up, often got a lot dumped on her because my dad was focused (and I learned that focus). And so when you've got family needs, you have to integrate that thinking into what you can do.

Between some health problems in our family and the pandemic, I would say that it's one of the least active times in my life. And that includes getting out and talking to kids. We do that, Marty and I both. In fact, he's really good at it. He loves talking to kids. So we do that but I haven't made it a focus like he has.

RML: I hope that many people, especially some of our younger members, will read this conversation and feel the same way I do: The things you've done are quite astonishing. You see opportunities and you know how to address them. And you've done that sequentially with a whole range of things.

MRS. HARRIS: There are two things that I credit that to. First, I can't read very well, so I never got buried in an individual discipline like engineering. I had to look across and consolidate my views into pretty principles. Second, I listened to all those phone calls when I was young. I listened to people talk about what they were doing, solving big problems, and making trouble. It was educational.

RML: I'm always curious about the way nature treats us all, and here you're describing a situation where reading is difficult for you, but you have such clarity of vision when it comes to other things. You can see a need and you can respond to it. It's a different form of reading. It's not reading text. It's reading society. Or reading our culture. And that's an incredibly valuable capacity.

MRS. HARRIS: That's why I think that, going forward, many of the pressing problems in the world are going to be solved by teams of people. They'll be cognitive scientists and designers. Engineers who need to embrace each other's work. Because problem-solving by going on a bench and making something or coding something for a system as an individual isn't going to be enough for the big problems that we've created. Our systems have simply become too complicated.

RML: That's a good note on which to close. I've enjoyed this enormously, Arlene. Thank you for being with us today.

MRS. HARRIS: I appreciate it. You've drummed up some of my old memories.

KG: I echo what Ron said. This has been a super inspiring conversation, and I have no doubt that it will be inspiring for our readers as well.

NAE News and Notes

NAE Newsmakers

D**iran Apelian**, distinguished professor of materials science and engineering, University of California, Irvine, was awarded the **WPI Presidential Medal** of the Worcester Polytechnic Institute on March 22 at the inauguration of President Grace J. Wang. The WPI Presidential Medal was established in 2001 to recognize individuals who represent the ideal of the "technological humanist." Dr. Apelian was recognized for pioneering work in solidification processing, metal processing, powder metallurgy, and digital manufacturing.

ACS has announced that it will honor **Frances H. Arnold**, Linus Pauling Professor of Chemical Engineering, Bioengineering and Biochemistry, California Institute of Technology, with the **2025 Priestley Medal**. The medal is awarded annually to a single individual for distinguished services to chemistry. Professor Arnold is being honored "for her pioneering contributions to the development of directed evolution as a method for chemical and biological design." She will receive the medal and deliver an address on March 25 at the ACS Spring 2025 meeting in San Diego, California.

AIAA and NAE have announced that **Penina Axelrad**, distinguished professor aerospace engineering sciences, University of Colorado Boulder, is the recipient of the **2024 Yvonne C. Brill Lectureship in Aerospace Engineering**. Dr. Axelrad will present her lecture, "The Evolution and Impact of Global Navigation Satellite Systems," at the NAE Annual Meeting on October 1.

Sangeeta N. Bhatia (NAS, NAM), investigator, Howard Hughes Medical Institute, Massachusetts Institute of Technology, has been named a **2024 American Association of Cancer Research Fellow**.

Donna G. Blackmond (NAS), John C. Martin Endowed Chair in Chemistry, Scripps Research, has been elected a member of the **Royal Society**. Elected as **foreign members** are **Emily A. Carter** (NAS), Gerhard R. Andlinger Professor in Energy and the Environment and professor of mechanical and aerospace engineering, Princeton University; **William D. Nix**, Lee Otterson Professor of Engineering (Emeritus), Stanford University; and **Ares J. Rosakis** (NAS), Theodore von Karman Professor of Aeronautics and Mechanical Engineering, California Institute of Technology, have been named **foreign members of the Royal Society**, the United Kingdom's national academy of sciences, the oldest scientific academy in continuous existence.

Bimal K. Bose, Condra Chair Professor Emeritus in Power Electronics, University of Tennessee, Knoxville, has been elected a **Fellow of International Core Academy of Sciences and Humanities** for "distinguished contributions to the field of engineering science and power electronics."

Vinton G. Cerf (NAS), vice president and chief internet evangelist, Google LLC, and **Robert E. Kahn** (NAS), president and CEO, Corporation for National Research Initiatives, were dual awardees of the **2024 Washington Award**. This prestigious award is conferred upon an engineer(s) whose professional attainments have preeminently advanced the welfare of humankind. Drs. Cerf and Kahn are recognized as "fathers of the internet" and were chosen for their design of transmission control protocols/internet protocols (TCP/IP) for managing information packet addressing and forwarding to and from proper destinations (making sure they don't get lost). The award was presented during Engineers Week in February.

Aart J. de Geus, chairman and co-CEO, Synopsys Inc., has been selected to receive the semiconductor industry's highest honor, the **Robert N. Noyce Award**. Dr. de Geus is a universally respected leader and visionary in the semiconductor industry and is honored for his landmark achievements in EDA technology. The award will be presented in November at SIA's awards dinner in San Jose, California.

In November, **Nicholas M Donofrio**, CEO, NMD Consulting LLC, will be named a **2024 Sigma Xi Fellow** at the society's annual conference. He is recognized for his innovation and career accomplishments, which have been focused on advancing education, employment, and career opportunities for underrepresented minorities and women in STEM disciplines.

Elazer R. Edelman (NAM), director, Institute for Medical Engineering & Science, and the Edward J. Poitras Professor in Medical Engineering and Science, Massachusetts Institute of Technology, has been awarded the **2024 Founders Award** from the Society for Biomaterials. This prize is awarded to an individual who has made a long-term, landmark contribution to the biomaterials discipline. Dr. Edelman pioneered the rational development of endovascular stents, enabling stent-based drug delivery that has changed the practice of medicine.

Eric D. Evans, director, MIT Lincoln Laboratory, was presented with the **Department of Defense Medal for Distinguished Public Service** on May 31. The award, the highest honor given to private citizens for their significant service to the DOD, was given to Dr. Evans for his leadership as director of MIT Lincoln Laboratory and as vice chair and chair of the Defense Science Board.

Darío Gil, senior vice president and director, IBM Research, has been chosen to **chair the National Science Board**. It has been more than 30 years since the NSB had a chair who was working in industry at the time of his or her election. The NSB is the governing board of the National Science Foundation and the advisor to Congress and the president on policy matters related to STEM research and STEM education.

Sharon C. Glotzer (NAS), John W. Cahn Distinguished University Professor of Engineering, Stuart W. Churchill Collegiate Professor of Chemical Engineering, and Anthony C. Lembke Department Chair of Chemical Engineering at the University of Michigan, Ann Arbor, is the recipient of the **2024 Fomms Medal**. She is recognized for her research on computational assembly science and engineering that aims toward predictive materials design of colloidal and soft matter. The Fomms Medal honors "profound and lasting contributions by one or more individuals to the development of computational methods and their application to the field of molecular-based modeling and simulation."

Ignacio E. Grossmann, Rudolph R. and Florence Dean University Professor, Carnegie Mellon University, has been selected by AIChE to **deliver the 2024 John M. Prausnitz AIChE Institute Lecture**. Professor Grossmann will discuss his application of models and algorithms in the optimal synthesis and planning of sustainable chemical process and energy systems at the 2024 AIChE Annual Meeting in October.

Robert D. Hanson, professor emeritus of civil engineering, University of Michigan, was awarded the **George W. Housner Medal for 2024**. The Earthquake Engineering Research Institute presented the award in April during their annual meeting in Seattle. Dr. Hanson was chosen in recognition of his contributions to earthquake hazard reduction through education, research, international cooperation, and public service.

Wesley L. Harris, Charles Stark Draper Professor of Aeronautics and Astronautics, Massachusetts Institute of Technology, was **honored at the National Society of Black Engineers** (NSBE) Boston Professionals 6th Annual Inspire STEM Scholarship and Awards Gala in February. Professor Harris was recognized for his "exceptional leadership, career achievement, and significant contributions to our community and the advancement of STEM initiatives."

Robert S. Langer (NAS/NAM), institute professor, Massachusetts Institute of Technology, and **Chad A. Mirkin** (NAS/NAM), professor and director of the International Institute for Nanotechnology, Northwestern University, share the **2024 Kavli Prize in Nanoscience** with NAS member A. Paul Alivisatos, president of the University of Chicago. The citation reads, "for pioneering work integrating synthetic nanoscale materials with biological function for biomedical applications."

Margaret R. Martonosi, Hugh Trumbull Adams '35 Professor, Princeton University, received the **ACM Frances E. Allen Award for Outstanding Mentoring**. Professor Martonosi is recognized for outstanding and far-reaching mentoring at Princeton University, in computer architecture, and to the broader computer science community. The award is presented biennially to an individual who has exemplified excellence and/or innovation in mentoring, with particular attention to recognition of individuals who have shown outstanding leadership in promoting diversity, equity, and inclusion in computing.

Carver A. Mead (NAS), Gordon and Betty Moore Professor of Engineering and Applied Science Emeritus, California Institute of Technology, has been honored with the **Misha Mahowald Recognition of Lifetime Contribution to Neuromorphic Engineering**. The citation reads: "Carver Mead established the field of Neuromorphic Electronic Engineering. His creativity and vision has inspired a generation of scientists, technologists, and entrepreneurs to emulate brain-like information processing in electronic systems." The award was presented on April 23 at a ceremony during the Neuro Inspired Computational Elements Conference in La Jolla, California.

Teresa H. Meng, Reid Weaver Dennis Professor, Stanford University, will receive the **2024 Marconi Prize** during the Marconi Society

Awards Gala and Executive Forum in Bologna, Italy, in October. Dr. Meng is being honored for her fundamental technical contributions to and commercial leadership in all-CMOS Wi-Fi technology, leading to its widespread use in practice. This year's Gala holds special significance as it coincides with the 150th anniversary of the birth of Guglielmo Marconi, the revered pioneer of wireless communications, and commemorates the 50th anniversary of the Marconi Society.

Shuji Nakamura, professor of electrical and computer engineering, University of California, Santa Barbara, has been elected to the **Engineering and Science Hall of Fame**. The citation reads, "for pioneering invention and development of the blue light emitting diode (LED), a major breakthrough in lighting technology which made possible the white light energy-efficient LED lighting in wide use today."

Arogyaswami J. Paulraj, professor emeritus, Stanford University, has been awarded the Royal Academy of Engineering's most prestigious individual award, the **Prince Philip Medal**. He was presented with the award by Her Royal Highness the Princess Royal, Royal Fellow of the Academy, in London on June 11. Dr. Paulraj was recognized for pioneering the invention of Multiple-Input, Multiple-Output (MIMO) technology, the foundation for all current and future broadband wireless communications.

H. Vincent Poor (NAS), Michael Henry Strater University Professor, Princeton University, has been chosen as a **Corresponding Member of the Australian Academy of Science**. Professor Poor is recognized for his pioneering research in communication theory, signal processing, and wireless networks.

Zorana B. Popovic, distinguished professor, Lockheed Martin Endowed Chair in RF Engineering, University of Colorado Boulder, was named a **2023 fellow of the National Academy of Inventors**. She was elected for her "prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on the quality of life, economic development, and welfare of society."

Joan B. Rose, Homer Nowlin Chair in Water Research, Michigan State University, was honored for her lifetime of water research with the **International Water Association Global Water Award** on August 10 at the IWA World Water Conference in Toronto.

Kamal Sarabandi, Fawwaz T. Ulaby Distinguished University Professor of Electrical Engineering and Computer Science and the Rufus S. Teesdale Professor of Engineering, University of Michigan, is a 2024 recipient of an **Ellis Island Medal of Honor**. The awards materials describe him as "a legendary figure in the field of engineering."

Raj N. Singh, regents professor, Oklahoma State University, received the OSU-Tulsa **2024 President's Outstanding Research Award** for his research excellence at OSU. He is recognized for scientific and technological contributions to ceramic matrix composites, diamond thin films, BNNT, electrolyte retainer for molten carbonate fuel cells (MCFC), electrolyte for Na-S battery, self-healing glass seals, and electrolyte and electrodes for solid oxide fuel cells (SOFC) and ferroelectric materials with large strain capability.

Pol D. Spanos, L.B. Ryon Professor in Mechanical and Civil Engineering, Rice University, has been awarded the **2024 Blaise Pascal Medal in Engineering**. Professor Spanos was recognized for his "theoretical insights, ranging from equivalent linearization to statistical quadratization, which have significantly advanced our understanding of structural behavior. These insights have not only led to more accurate predictions but have also empowered engineers to make better-informed decisions." He will receive the medal in October during the 2024 Symposium and Ceremony of the European Academy of Sciences in Lisbon, Portugal.

Gerald J. Sussman, Panasonic Professor of Electrical Engineering, Massachusetts Institute of Technology, received the **2024 Taylor L. Booth Education Award**. The citation reads: "For providing a novel, long-lasting, and inspirational approach to the teaching of computer science through functional programming that has impacted students from a broad range of STEM disciplines."

Hongtei E. Tseng, distinguished university professor, Department of Electrical Engineering, University of Texas Arlington, has been awarded the **2024 Soichiro Honda Medal**, which recognizes an individual for an outstanding achievement or a series of significant engineering contributions in developing improvements in the field of personal transportation. Dr. Tseng was chosen for his "contributions to automotive computer controls, estimation, and fault detection, resulting in improved safety and performance of millions of vehicles worldwide."

Gordana Vunjak-Novakovic, university professor and Mikati Foundation Professor of Biomedical Engineering, Columbia University, has received a **Chan Zuckerberg Biohub New York** (CZ Biohub NY) **Investigator Award**. She received the award for an innovative project designed to build entirely new tools for instructing and characterizing immune cells. The study, which will investigate and treat immune modulation of cancer metastasis, is expected to gain new insights into the interactions of these cells with their environment. The Investigator Program at CZ Biohub NY provides five years of funding for research by world-renowned scientists, engineers, and technologists in the New York area.

The **2024 Research Innovation Award** has been awarded to **Paul K. Westerhoff**, Regents Professor Fulton Chair of Environmental Engineering, Arizona State University, by the Water Research Foundation (WRF). Dr. Westerhoff has been an innovative force in water since the early stages of his career. He received a WRF award in 2006 for his research on the removal of engineered nanomaterials during wastewater treatment, which led to the development of new analytical methods.

Andrew J. Whittle, Edmund K. Turner Professor, Massachusetts Institute of Technology, was selected to give the **2024 Karl Terzaghi Lecture**. Professor Whittle was honored for groundbreaking contributions in the formulation of constitutive models for representing the complex mechanical properties of soils and their application in predicting the performance of foundations and underground construction projects.

Academia Sinica held its biennial Convocation of Academicians in July and announced the election of 28 new Academicians and two Honorary Academicians. NAE members **elected as Academicians** are **Tsu-Jae K. Liu**, Dean & Roy W. Carlson Professor of Engineering, University of California, Berkeley; **Lee-Lueng Fu**, JPL Fellow, NASA Jet Propulsion Laboratory, Caltech; **David Y. Pui**, regents professor, University of Minnesota; and **Douglas C. Yu**, distinguished fellow and R&D vice president, Taiwan Semiconductor Manufacturing Co. Ltd. **John L. Anderson**, president, National Academy of Engineering, was **elected Honorary Academician**.

NAE members elected to the Royal Society in 2024/25 are: **Ares J Rosakis**, Theodore von Karman Professor of Aeronautics and professor of mechanical engineering, California Institute of Technology (foreign member).

The NAE: Celebrating 60 Years of Engineering

John L. Anderson, NAE President

This year, the National Academy of Engineering celebrates its 60th anniversary.

Anniversaries are more than a celebration of our past. They present an opportunity to learn from the past *and* move confidently into the future. Anniversaries are a time to ask and answer important questions like: What more can we do? What issues should we address? What actions can we take to improve our lives and our planet? What partnerships should we build to advance the engineering profession? What initiatives should we support to raise awareness of engineering and engineers? We must remain aware that engineering touches every person every day—many times. So we must be cognizant of our responsibility to do not only great things but also *good* things, and minimize unintended consequences.

One of the NAE's newest offerings that brings the societal impacts of engineering to the forefront is the annual NAE Lecture on Engineering and Society, which tackles current challenges and emphasizes engineering's impact on society. First featured at the 56th NAE Annual Meeting in 2020, John Brooks Slaughter addressed the issues of racial justice and equity, noting that Americans are living through a critical period in the history of our nation, in which we are facing several potentially cataclysmic events at once such as climate change, the COVID pandemic, and the social and political challenges emanating from the ignominious history of racism and anti-Blackness that has crippled our nation for 400 years.[1] Additional topics addressed in this lecture series included artificial intelligence (AI), energy-climate challenges, and rehabilitation engineering, which will be presented at the 2024 NAE Annual Meeting.

[1] See Galvin M. 2020. We must let opportunity meet talent. National Academies of Sciences, Engineering, and Medicine, Oct 15. Online at https://www.nationalacademies.org/news/2020/10/we-must-let-opportunity-meet-talent. A video recording of John Brooks Slaughter's lecture can be found at www.youtube.com/watch?v=xcy6WwPxjGE.

Founding members attending the first annual meeting of the National Academy of Engineering. April 27–29, 1965. From left to right, standing: Ernst Weber, Michael L Haider, Charles A. Thomas, William L Everitt, Julius A. Stratton, Frederick E. Terman, Thomas K. Sherwood, Oark B. Millikan, James N. Landis, Hendrick W. Bode, and Nathan M. Newmark. Seated: Thomas C. Kavanagh, Augustus B. KinzeI, Eric A. Walker, and first NAE Secretary Harold K. Work.

1964 → 2024 Member Elections

Metric	Class of 1964	Class of 1992	Class of 2024
Total	25	79	114
% Business	56%	54%	50%
% Academic	36%	32%	38%
% Women	0%	4%	24%
% Minority	0%	4%	9%

International Members not included in data

Over the years, the NAE membership has increased its diversity.

Throughout the past 60 years, the NAE has been very successful in effecting positive change, and we have much to celebrate. As the trusted voice in engineering, innovation, and technology, the NAE has taken the leading role to "advance the welfare and prosperity of the nation by providing independent advice on matters involving engineering and technology, and by promoting a vibrant engineering profession and public appreciation of engineering." Our reports, as part of the National Academies of Sciences, Engineering, and Medicine, are the gold standard for objective, fact-based studies of important topics, including mitigating and adapting to climate change, developing mRNA vaccines, safeguarding our food and water supplies, and protecting our networks and power systems. We inform policy with evidence, spark progress and innovation, and confront challenging issues for the benefit of society. We have also been the rallying force behind diversity, equity, and inclusion in the profession and in STEM education. And we have laid the foundation to strengthen collaboration at the local, national, and international levels. Past programs such as the Grand Challenges in Engineering, announced in 2008, have brought engineering to the forefront of the public's attention.

Our current programs, such as The Grainger Foundation Frontiers of Engineering, which supports early-career engineers, and the NAE's award-winning EngineerGirl, which *inspires young women to pursue a career in engineering*, remain strong and vibrant. One of our new programs, the Forum on Complex Unifiable Systems (FOCUS), engages multi-stakeholders to advance understanding of complex technical and social systems and identify unifiable approaches to better manage them. These programs allow for deeper collaboration on both the local and international levels.

As we celebrate the NAE's 60th anniversary, our goal is to propel the NAE and engineering into the future by building an *inclusive* engineering profession, nurturing relationships and programs that advance engineering efforts, and spreading the word about the myriad ways engineering and the NAE have made positive impacts in our world. This also entails being ever vigilant in efforts to identify and resolve potential unintended consequences of new technologies.

In recent months, I have had the distinct pleasure of sitting down with engineering leaders to discuss their success and the obstacles they overcame to become pioneers in engineering. The video series *Conversations with Engineering Pioneers* features **John Brooks Slaughter**, who championed diversity in engineering and engineering education; Holocaust survivor and pioneer of computer software for analysis of large structural systems **Steven J. Fenves**; **Frances Arnold**, who received a Nobel Prize in chemistry for directed evolution of enzymes; **Martin Cooper**, who is widely regarded as the father of cellular telephony; and **Andrew Viterbi**, wireless communications pioneer and inventor of the Viterbi algorithm. Throughout 2024, a new engineering pioneer is showcased on the NAE website, with future individuals to include aeronautics pioneer **Sheila Widnall** and biomedical pioneer **Bob Langer**.

When the NAE was founded in 1964, it was a homogenous group of white males who held high-ranking leadership positions at major US corporations and highly recognized universities. In its first three decades of existence, very few women, people of color, and innovators in small businesses were elected to the NAE. Today NAE annually elects about 110 new US members representing diverse demographics, experiences, and positions. This diversity has strengthened the NAE in its ability to advise the nation and promote the engineering profession. It also sets the tone for achieving the diversity of the engineering workforce that is needed in the future to advance technology for the good of the nation.

In May, the NAE released phase two of the "Calling All Big Thinkers" public awareness campaign, which showcases the beauty, power, and excitement of engineering and puts forth the message that anyone with the ability to "think big" can be an engineer. And the NAE's *Engineering the Future: Diversity Dialogues* podcast, launched on June 17, in celebration of Juneteenth, features experts discussing ways to innovate with diversity and inclusion. Tune in to the discussion, hosted by NAE member Wanda Sigur, on Apple, Spotify, Audible/Amazon Music, and Goodpods.

As part of the 2024 NAE Annual Meeting, which will take place September 29–30 at the National Academy of Sciences building in Washington, DC, the NAE will showcase these programs as well as incorporate a celebration of 60 years into our new member induction ceremony. The event will be livestreamed from the NAE website.

NAE has much to celebrate. I hope you will join us in celebrating the NAE's 60 years of providing "leadership in a world of accelerating change."

2024 China-America Frontiers of Engineering Held Again as Point-to-Point Hybrid

From June 17–19, the 2024 China-America Frontiers of Engineering Symposium held a hybrid meeting of early-career engineers from China and the United States. NAE member **Eleanor Allen**, founder and CEO of Catapult for Change, and Jing Cheng, Cheung Kong Professor of Biomedical Engineering at Tsinghua University, returned as co-chairs for the meeting, which was held two years ago also as a point-to-point meeting. NAE and the Chinese Academy of Engineering (CAE) jointly hosted the meeting.

Like the 2022 event, the meeting was originally scheduled to be held in China, but with travel to and within China still restricted, the NAE and the CAE decided that the NAE would host the meeting and CAE participants would attend at the National Academies' Beckman Center in Irvine, California. Unfortunately, additional travel complications from China to the United States limited the number of participants available to attend, so both academies decided to continue the meeting as a point-to-point hybrid. US participants assembled at the Beckman Center, and CAE participants gathered in Beijing. With the virtual stage set, attendees actively participated in the breakout sessions and technical presentations. With the substantial 12-hour time difference between California and China, the US participants were afforded a separate agenda of poster sessions, breakouts, and tours of labs at UC-Irvine. The joint meeting's technical session topics were Nanotechnology for Health, Energy Transitions and Challenges, Knowledge Engineering and Transportation, and A Sustainable Ocean Future.

Nanotechnology continues to emerge as a powerful healthcare tool for diagnosis, treatment, and prevention of diseases. Targeted drug delivery, using engineered nanoparticles, is one of the most notable applications of nanotechnology in healthcare. The first talk described the benefits of nanoparticle drug delivery for cardiovascular disease, immunology, and other applications. The next presenter described the growing number of high-resolution microscopy available for imaging at the nanoscale. The final two presenters provided more technical insights of nanoprobe imaging of metabolic activities and nanofiber scaffolding.

The session on Energy Transitions and Challenges described efforts in nations, regions, and locales that are attempting to move their energy sector

The Beckman Center group of attendees at the 2024 China-America Frontiers of Engineering Symposium. Another group assembled in Beijing, China, and connected using point-to-point hybrid technology.

towards zero-carbon energy sources and away from fossil fuels. A pivotal moment in time for this discussion, this session provided a forum to discuss how alongside the energy transition challenges are critical and emerging technological innovations. The first talk described emerging power solutions for internet of things (IoT) sensor nodes, based on resonating energy harvesters. The next presenter proposed an Energy-Material Cycles (EM-cycles) model that could shift the discussion of tradeoffs that exist across energy systems. This discussion also broadly discussed how analytical methods can shape the social and political understanding of the "energy transition." The next talk discussed a new distributed paradigm of the electricity grid, which would involve grids using a layered architecture of operating principles. The last talk focused on addressing energy poverty in the US energy transition, and discussed some ongoing research related to this.

The Knowledge Engineering and Transportation session discussed innovative ways that the field has evolved from its initial data analysis and predictive capabilities and has now become an integral piece to addressing transportation challenges. The first session provided an overview of ongoing research designing robot perception algorithms and systems. The next session described an innovative diagnostic tool that is used to conduct fault diagnosis for China's high-speed railway systems. This was followed by a presentation of a unique study that involved a partnership with the ridesharing platform Lyft, where an online reinforcement learning approach helped create a more efficient matching algorithm. To close the session, a speaker presented on a decision recommendation framework that could be used to optimize airline network operations.

The final session of the meeting explored emerging technologies designed to achieve a alance between the acquisition and use of ocean resources and the minimization of their impact on marine communities. The first talk described an innovative approach to sustainable exploitation of renewable energy and aquaculture: a modular, multipurpose floating device that integrates a wing turbine, wave energy converter, and a fish cage. The next speaker discussed the development of a high-efficiency and low-cost ceramic fiber-based carbon-carbon composite solar absorber that aids in seawater desalination. Lastly, a virtual speaker discussed the application of new observational technologies that can advance the understanding of bidirectional connection between climate and the ocean carbon cycle.

The symposium program, list of attendees, and presentation videos and slides are available at www.naefrontiers.org.

Special thanks to NAE member **Diran Apelian**, distinguished professor of materials science and engineering at the University of California, Irvine, who arranged for the US attendees to visit several institutes and research facilities on campus: the National Fuel Cell Research Center and Horiba Institute for Mobility and Connectivity, the Irvine Materials Research Institute, and the Advanced Casting Research Center.

Funding for this activity was provided by The Grainger Foundation and the National Science Foundation. The next CAFOE meeting will be held in China in 2026.

The NAE has been hosting an annual US Frontiers of Engineering meeting since 1995 and, in addition to CAFOE, has bilateral FOE programs with Germany, Japan, and the European Union. These meetings bring together highly accomplished early-career engineers from industry, academia, and government and provide an opportunity to learn about developments, techniques, and approaches at the forefront of fields other than their own. The program also facilitates the establishment of contacts and collaboration among the next generation of engineering leaders.

For more information about the activity, or to nominate an outstanding engineer to participate in future Frontiers meetings, go to www.naefrontiers.org or contact Vernon Dunn at vdunn@nae.edu.

Tensions at the Edge: NAE Regional Meeting and Symposium Hosted by the University of California, Davis

By Raissa M. D'Souza

In May 2024, the University of California, Davis, hosted the National Academy of Engineering Regional Meeting and Symposium entitled "Tensions at the Edge: Competing Objectives in Engineering Solutions to Society's Most Pressing Problems."

Engineers and scientists usually go deep into the technical aspects of their work, but the symposium provided an opportunity to focus on the larger landscape, including the unintended consequences of technological solutions and the diversity of interests that must be represented to make decisions for the benefit of humanity. Tensions include those between disciplines, between theory and practice, and between competing objectives.

Richard Corsi, dean of the UC Davis College of Engineering, and **John L. Anderson**, president of the NAE, provided welcoming remarks. These highlighted the key role the NAE plays in enabling engineering solutions to societal problems, including the call to bring "big thinkers" together and the NASEM Consensus Study Reports, such as the one on health risks of indoor air pollutants recently chaired by Corsi. Recent highlights from the College of Engineering were then presented, including their strategic research vision focused on strengthening climate resilience, revolutionizing energy systems, advancing human health, and transforming mobility. Associate Dean of Research Raissa D'Souza, who designed the symposium program, then presented an overview of the motivations and goals, including inspiring the audience to tackle grand societal problems with engineering solutions.

"Tensions in the energy ecosystem, from renewables to data centers," the first presentation, was by Vinod Narayanan, professor of mechanical and aerospace engineering at UC Davis. Highlights include showing that the United States has enough renewable resources to fuel our energy demands, but the low cost of natural gas precludes large-scale market adoption. There is also a staggering growth in the demand for energy, fueled by the growth of data centers and clean manufacturing practices. Potential solutions include multifunctional heat pumps that transform waste heat and modular data centers with minimal energy and water consumption.

"Tensions in health and AI: Towards accessible smart health services" was then presented by Chen-Nee Chuah, professor of electrical and computer engineering at UC Davis. Highlights include how smart sensors and edge technologies stand to transform healthcare, from monitoring and diagnostics to personalized therapeutics. Technical challenges include new machine learning approaches, validation, and data privacy and security. Socioeconomic challenges include engaging health care providers and bridging the digital divide.

"Tensions in concurrent engineering of food, energy and materials systems" was then presented by Sabbie Miller, associate professor of civil and environmental engineering at UC Davis. Highlighted was the massive increase in demand for building materials, energy, and food fueled by our growing global population. A wholistic view of a virtuous cycle of biowaste, new manufacturing approaches for concrete and plastics, and carbon sequestration solutions was presented as a path forward.

The symposium then featured eight "flash talks" on engineering solutions, including drone networks for early forest fire detection, sustainable turbine blades made from mycelium, climate engineering through radiative cooling, ocean water sequestration of carbon dioxide, low-cost approaches to indoor air quality, electric vehicles and grid dynamics, accelerating RNA vaccine discovery, and AI and food systems.

The symposium concluded with a vibrant panel discussion moderated by D'Souza, featuring: Brett Singer, a senior scientist at Lawrence Berkeley National Lab and expert on building health and transforming basic research into policy; **Robert Kiss**, an alum of the UC Davis College of Engineering, member of the NAE, world leader in biotherapeutics and the executive vice president of Technical Operations at Upside Foods, which creates cultivated meat grown from animal cells; Cristina Davis, the associate vice chancellor for Research at UC Davis and an expert in biological and chemical sensing with extensive experience in the IP space; Tony Meyers, the chief operating officer of the California State Water Project, who has overseen massive and transformative engineering infrastructure projects. The discussion included articulating the biggest challenges and associated tensions these leaders are facing, how to scale up cultivated meat, the role of the national labs, enabling team science, how to modernize California's water system while protecting the ecosystem, the role of the NAE, and the "silver tsunami" of retirements facing the critical infrastructure community.

The meeting also featured tours of several state-of-the-art College of Engineering facilities, such as the Center for Nano-MicroManufacturing (CNM2), the Diane Bryant Engineering Student Design Center, and the brand-new UC Davis Coffee Center. Over 100 people participated in the meeting, from several different regions of the country, including many graduate and undergraduate students.

A Center for West Coast Engineering Enterprise

The Arnold and Mabel Beckman Center sits on seven acres of land adjacent to the University of California, Irvine. With more than 700 NAE members located on the West Coast, the facility allows the Academies to maintain a strong presence in the region and provides the space to easily engage with members and volunteers through member gatherings, committee meetings, and public forums. The Center is also open to business and university communities to convene and discuss matters of science, technology, and education.

In addition to the numerous programmatic activities and conferences that take place at the Beckman Center, the NAE hosts its annual National Meeting and the Lilian Gilbreth Lectureships to engage members and give hundreds of local high school students a chance to hear about the exciting fields in engineering and STEM. This opportunity to converse with leaders who present on leading-edge engineering topics, such as robotics, space exploration, and environmental and biomedical engineering, is a great way to get a younger generation interested in the engineering profession and increase diversity in the field.

The Beckman Center is supported through a modest endowment sup-

Local high school students attend the Lillian Gilbreth lectures at the Beckman Center.

Mabel and Arnold Beckman

plemented with critical funding through its unrestricted annual donations. To make needed improvements and secure the finances of the Center, the NAE has embarked on a fundraising effort to grow the endowment to $10 million to ensure it can cover its share of the expenses in perpetuity.

Thanks to the generosity of 11 major donors, we have already raised an impressive $2.9M through the campaign. As of August 6, 2024, six of these individuals and their spouses have already pledged more than $100K each to the NAEF Beckman Center fund. These principal donors include:

- John L. and Patricia Anderson (NAE, '92)
- Ross and Stephanie Corotis (NAE, '02)
- John and Candace Hallquist (NAE, '07)
- Wesley L. Harris (NAE, '95)
- Robin K. and Rose McGuire (NAE, '07)
- Alton D. and Julie Romig (NAE, '03)

> "The Beckman Center is one of the NAE's greatest resources and we created the NAEF Beckman Endowment to allow the NAE to make the most of the facility in the near future and beyond."
>
> – *Ross and Stephanie Corotis*

There are numerous avenues to join these charitable donors in our efforts. To commemorate **John L. Anderson's** NAE presidency and his tireless advocacy for maintaining the Beckman Center and expanding its vibrant programming, the Academy has established a special funding opportunity to name the Beckman Center Boardroom in his honor. We must raise $3M to realize this goal for the NAEF Beckman Endowment before the end of President Anderson's term in 2025. Space in the building and the Beckman Auditorium seats are available for members and friends to name after themselves, a loved one, or a mentor.

The Beckman Center itself is named after Dr. **Arnold O. Beckman** (NAE, '67), who was a pioneer in modern analytical instrumentation. The founder of Beckman Instruments, Dr. Beckman was responsible for the invention of the acidimeter, a device that shaped modern analytical chemistry and earned him recognition in the National Inventors Hall of Fame alongside other talented scientific minds like Edison, Bell, Ford, and Pasteur. In 1967, he was elected to the National Academy of Engineering and received the NAS Public Welfare Medal in 1999, the NAS's most prestigious award.

Beyond his direct contributions to science and engineering, Dr. Beckman and his wife, Mabel, recognized the important role philanthropy plays in ensuring the vitality of the nation's scientific enterprise. In 1977, the pair established the Arnold and Mabel Beckman Foundation and dedicated their lives to supporting medical, scientific, and engineering institutions. In 1988, the foundation provided a generous grant that realized a West Coast campus for the Academies.

"Arnold Beckman is not only considered one of the top inventors of scientific instruments but also one of the greatest philanthropists of his time. The Beckman Center is a testament to his and Mabel's love and dedication to science, engineering, and technology."

– John Anderson

From pioneering scientific discoveries to committing to the longevity of the scientific and engineering communities through their philanthropy, Arnold and Mabel Beckman dedicated their lives to ensuring a bright future for the scientific and engineering enterprise. The National Academy of Engineering is honored to continue their mission by making the Arnold and Mabel Beckman Center a warm, welcoming place where all our members, friends, and the greater engineering community can better engage and advance scientific and engineering enterprises.

EngineerGirl 2024 Writing Contest Winners Announced

The National Academy of Engineering announced the winners of its 2024 EngineerGirl Writing Contest. This year's competition asked students in elementary through high school to write an essay exploring the lifecycle of an object that is used in daily life. This year's contest prompt, "The Secret Life of Everyday Items," asked students to focus on the specific contributions and roles of engineers throughout the entire process of transforming raw materials into consumer products. Prizes were awarded to students based on grade level.

"Congratulations to the 2024 EngineerGirl Writing Contest winners for their creativity in crafting essays that highlight the core of engineering, which is ingenuity and bringing ideas to life," said NAE President **John L. Anderson**. "These students skillfully showcased the key roles that engineers play throughout all processes of innovation, from design to development to implementation."

NAE congratulates the following first place winners:

- ***Hiya Ghosh***, a third-grade student at Eagle Point Elementary School in Oakdale, Minnesota, placed first among elementary school students for her essay "Toothpaste Engineering is super exciting!"
- ***Eesha Vanamala***, an eighth-grade student from Brooklawn Middle School in Morris County, New Jersey, won first place among entries from middle school stu-

dents for her essay exploring "The Story of an Arduino."

- ***Vivian Bootz***, a 10th grade student at Kewaunee High School in Kewaunee, Wisconsin, placed first among high school students for her essay titled "Paper's Life."

Awards for contest winners are $1,000 for first place, $750 for second place, and $500 for third place. Winning entries, along with honorable mention entries, are published on the EngineerGirl website. Additional winners are listed below.

Elementary Winners:

- Second Place: Julia, "The Secret Life of a Pencil"
- Third Place: Mini Murthy, "Pencil, An Engineering Miracle"
- Honorable Mention: Addie DeMarco, "Engineers throughout lifecycle of paper"
- Honorable Mention: Athena Brown, "Rainbow's Story"

Middle School Winners:

- Second Place: Dalia Azam-Naseeruddin, "The Age of Plastics"
- Third Place: M. Goodwin, "Engineering Limitless Lash Altitude"
- Honorable Mention: Aaliyah Azeez, "The Life Story of a Smartphone"
- Honorable Mention: Max Gerhardt, "The Story of the Bottle"

High School Winners:

- Second Place: Aiden Choi, "Puff Goes the Inhaler"
- Third Place: Divyansha Nashine, "Odyssey of the Hero of Oral Hygiene: The Electric Toothbrush"
- Honorable Mention: Ahana Gupta, "Engineering the Run"
- Honorable Mention: Serena Tsai, "Preservation of Knowledge: The Life Cycle of a Ballpoint Pen"

EngineerGirl is designed for girls in elementary through high school and offers information about various engineering fields and careers, answers to questions, interviews of engineers, and other resources on engineering. Surveys of contest participants indicate that 40 percent of girls say they are more likely to consider an engineering career after writing their essay. EngineerGirl is part of the NAE's ongoing effort to increase the diversity of the engineering workforce.

The National Academy of Engineering Launches Editorial Board

The National Academy of Engineering (NAE) has launched the NAE Editorial Board. Editorial board members will serve as advisors and ambassadors for *The Bridge*, the NAE's flagship quarterly, and *NAE Perspectives*, the digital, short-form commentary series. Meeting four times each year, the NAE Editorial Board will provide guidance on the overall direction of *The Bridge* and *NAE Perspectives,* review article drafts as appropriate, participate in the development of editorial strategies, and offer input on editorial policies.

Beginning as a bimonthly newsletter in March 1969, *The Bridge* has evolved into a quarterly magazine with a distribution of roughly 7,000 readers, including NAE membership, Congress, federal agencies, universities, libraries, and interested individuals around the country and the world. *The Bridge* publishes opinion and analysis on engineering research, education, and practice; science and technology policy; and the roles of engineering and technology in society. *The Bridge* seeks to inform and stimulate debate and dialogue among NAE members as well as policymakers, educators, business leaders, and other interested citizens.

NAE Perspectives, launched in July 2021, provides an opportunity for practitioners, scholars, and policy leaders to comment on developments and issues relating to engineering and to reflect on opportunities important to the advancement of the NAE's mission. The purpose of *NAE Perspectives* is to bring diverse voices and perspectives to discussions related to current issues, examine opportunities and challenges facing engineers and engineering, and to foster public engagement in engineering.

The NAE Editorial Board consists of NAE members and leaders in engineering and science communication across industry and academia. Ron Latanision, editor-in-chief of *The Bridge,* has been appointed as chair. The NAE Editorial Board will offer invaluable guidance as the NAE strives to boost the reach and impact of its publications, enabling the NAE to disseminate quality content pertaining to its mission throughout the engineering community and beyond. A full list of the inaugural NAE Editorial Board members is below.

NAE Editorial Board

Ronald Latanision Chair, Editor in Chief of *The Bridge*
Neil Armstrong Distinguished Visiting Professor, Purdue University; Senior Fellow, Exponent

Diran Apelian
Distinguished Professor, Materials Science and Engineering, UC Irvine's School of Engineering

Robert Brown
President Emeritus, Professor of Engineering, and Professor of Computing & Data Sciences, Boston University

Marian Croak
Vice President of Society Centered AI and Foundational ML, Google

Mariette Dichristina
Dean and Professor of the Practice in Journalism, the College of Communication, Boston University

Ann Karagozian
Distinguished Professor and Collins Aerospace Endowed Term Chair for Innovation, Department of Mechanical and Aerospace Engineering, Henry Samueli School of Engineering and Applied Science, University of California, Los Angeles; Director, UCLA Promise Armenian Institute

Jefferson C. Lievense
CEO, Lievense Bioengineering LLC

Piotr Moncarz
Founder and Vice Chair, XGS Energy; Adjunct Professor (Ret.), Stanford University; Former Senior Fellow, Exponent

Colin Parris
Former Senior Vice President and Chief Technology Officer, GE Digital

John Tracy
Former Chief Technology Officer and Senior Vice President of Engineering, Operations, and Technology, The Boeing Company

New NAE Staff

Alexandra Susano-Jarjuri

ALEXANDRA SUSANO-JARJURI has joined our organization as the new senior membership associate for data entry/management and member services. Alexandra brings with her a wealth of experience and a proven track record in project management. Alexandra has been with the International Center for Journalists since 2021, where most recently she served as a program manager, overseeing critical initiatives, developing strategic partnerships, and managing a team to ensure the successful execution of multiple global projects. We are excited about the expertise and enthusiasm she will bring to our projects and look forward to achieving great success together. You can reach Alexandra at asusanojarjuri@nae.edu or 202-334-2297.

AIDAN MONTANO joins the NAE as an intern. He is an undergraduate from Silver Spring, Maryland, studying mechanical engineering at Johns Hopkins University. His primary interest lies in biomechanics, and he conducts research on musculoskeletal tissue mechanics with the M-TEAM Lab at Hopkins. In his free time, he loves to hike, enjoy delicious food, play volleyball, and travel. As an intern, he hopes to help introduce engineering to a broader audience. Aidan can be reached at amontano@nae.edu.

Jordan Simmons

JORDAN SIMMONS joins us as senior membership & finance assistant. Her responsibilities include providing support for membership financials, managing membership dues, and responding to inquiries regarding *Memorial Tributes*. Jordan has a strong background in administrative support and brings diverse skills and a proactive approach to her assignment, ensuring that our processes run smoothly and efficiently. She began working with us as a temporary staff member primarily supporting the Finance team and will continue to support that team on a part-time basis. Previously, she worked as an accounting clerk at North Texas Job Corps and also as a freelance graphic designer, working on various projects requiring creativity and meticulous attention to detail. You can reach Jordan at jsimmons@nae.edu or 202-334-2945.

Calendar of Meetings and Events

July 31	CESER Advisory Committee Meeting
August 7–8	NAE Council Meeting Irvine, California
September 2	*Impacts of National Science Foundation Engineering Research Support on Society* Report Release Virtual
September 11–14	The Grainger Foundation Frontiers of Engineering Symposium Irvine, California
September 18–19	ASEE Inclusive Mindset Blueprint Convenings
September 27	NAE Council Meeting
September 29–30	2024 NAE Annual Meeting and 60th Anniversary Celebration
October 1	Yvonne C. Brill Lecture on Aerospace Engineering
October 23–24	ASEE Inclusive Mindset Blueprint Convenings
November 18–19	Workshop on "Issues at the Intersection of Engineering and Human Rights"

In Memoriam

Egil Abrahamsen, 100, president (retired), Det Norske Veritas Certification Inc., died April 14, 2023. Dr. Abrahamsen was elected an international member in 1978 for contributions to improved design of ship structures and leadership in international technical affairs.

William Anders, 90, founder and chairman, Heritage Flight Museum, died June 7, 2024. Dr. Anders was elected in 1984 for significant contributions to nuclear engineering, space exploration and research, and the development of national nuclear, aeronautical, and space policy.

Minoru S. Araki, 92, president (retired), Lockheed Martin Missiles & Space, died August 22, 2023. Mr. Araki was elected in 1990 for leadership in the design, development, and integration of very large spacecraft systems.

Satya N. Atluri, 78, presidential chair & university distinguished professor, Texas Tech University, died August 4, 2023. Dr. Atluri was elected in 1996 for contributions to computational methods for fracture mechanics and analysis of aerospace structures.

Seymour Baron, 99, director, Special Programs Office (retired), Medical University of South Carolina, died July 16, 2022. Dr. Seymour was elected in 1980 for being instrumental in the advancement of nuclear technology for research and energy applications.

Robert W. Bartlett, 90, dean emeritus, University of Idaho, died June 18, 2023. Dr. Bartlett was elected in 1995 for industrial and academic research in solution mining and extractive metallurgy and for significant applications to practice.

C. Gordon Bell (NAS), 89, Microsoft Emeritus Researcher, Microsoft Research Lab, died May 17, 2024. Dr. Bell was elected in 1977 for contributions to the architecture of minicomputers.

Andrew H. Bobeck, 91, supervisor, Device Development (retired), AT&T Laboratories, died December 14, 2017. Mr. Bobeck was elected in 1975 for contributions to the field of magnetic bubbles that have produced a new class of electronic devices.

Robert W. Bower, 87, professor emeritus, University of California, Davis, died January 27, 2024. Dr. Bower was elected in 1999 for inventing the self-aligned, gate ion-implanted MOSFET and for establishing ion implantation to fabricate semiconductor integrated circuits.

Robert W. Brodersen, 78, emeritus professor, University of California, Berkeley, died February 1, 2024. Dr. Broderson was elected in 1988 for pioneering contributions to very-large-scale integrated circuit design and to speech-processing technology.

Harvey E. Cline, 83, applied physicist (retired), GE Corporate Research and Development, died October 25,

2023. Dr. Cline was elected in 1993 for invention and development of novel solidification processes for composite materials and semiconductors.

James M. Coleman, 87, Boyd Professor, Louisiana State University and Agricultural and Mechanical College, died May 20, 2023. Dr. Coleman was elected in 1990 for pioneering contributions regarding deposition and stability of marine sediments and associated engineering applications.

Lynn A. Conway, 86, professor of electrical engineering and computer science, emerita, University of Michigan, died June 9, 2024. Professor Conway was elected in 1989 for the propagation of revolutionary methodology and tools for the design of VLSI (Very Large Scale Integration) systems.

Richard A. Conway, 92, environmental consultant (retired), Union Carbide Corporation, died January 8, 2023. Mr. Conway was elected in 1986 for outstanding contributions to environmental engineering through improved standards of assessment, and for development of improved water treatment processes for industrial wastes.

James Q. Crowe, 74, principal, J.Q. Crowe Company, died July 2, 2023. Mr. Crowe was elected in 2005 for contributions to the development and deployment of Internet-based communication technologies and services.

Ernest L. Daman, 99, chairman emeritus, Foster Wheeler Development Corporation, died February 25, 2023. Mr. Daman was elected in 1988 for significant and unique contributions to the design and development of power generation equipment, and for professional leadership.

F. Paul de Mello, 95, independent consultant, died December 11, 2022. Mr. de Mello was elected in 1984 for major advancements in dynamic analysis of electric power plants and systems benefiting design, control and training application.

Elisabeth M. Drake, 87, retired associate director for new energy technology, Energy Laboratory, Massachusetts Institute of Technology, died July 25, 2024. Dr. Drake was elected in 1992 for leadership in industrial safety and risk management.

Rodney Charles Ewing, 77, Frank Stanton Professor in Nuclear Security and Professor of Geological Sciences, Stanford University, died July 13, 2024. Professor Ewing was elected in 2017 for studies on the long-term behavior of complex ceramic materials to assess their suitability for engineered nuclear waste sequestration.

A.J. Field, 85, independent consultant, died January 25, 2009. Dr. Field was elected in 1974 for contributions to technology for drilling from floating structures and ships.

Hans G. Forsberg, 91, executive director, Aangpannefoereningens Forskningsstiftelse, died December 20, 2021. Professor Forsberg was elected an international member in 1994 for contributions to international cooperation and understanding in technology and policy issues.

Gerard J. Foschini, 83, distinguished inventor, Bell Labs, Alcatel-Lucent, died September 17, 2023. Dr. Foschini was elected in 2009 for contributions to the science and technology of wireless communications with multiple antennas for transmission and receiving.

Alan B. Fowler (NAS), 95, IBM Thomas J. Watson Research Center (retired), died August 4, 2024. Dr. Fowler was elected in 1990 for exploration of two dimensional quantum transport in inversion layers and related device kinetics.

W. Barney Gogarty, 94, president, W. Barney Gogarty & Associates Inc., died March 31, 2024. Dr. Gogarty was elected in 1990 for pioneering efforts in the research and development of the micellar-polymer flooding process and the transfer of this technology to the field.

Leonard Harris, 96, retired president, Resource Development Inc., died April 25, 2024. Mr. Harris was elected in 2022 for contributions to the development of mineral resources in Peru and advancing humanitarian programs in associated communities.

Robert J. Hermann, 90, retired private consultant, died October 5, 2023. Dr. Hermann was elected in 1989 for conceiving and guiding applications of space technologies to national security.

Mats H. Hillert, 97, professor emeritus of physical metallurgy, KTH-Royal Institute of Technology, died November 2, 2022. Dr. Hillert was elected an international member in 1997 for establishing a computerized thermodynamic/kinetic system to predict complex multi-component phase relationships, now adopted internationally for materials.

Evert Hoek, 90, Evert Hoek Consulting Engineer Inc., died July 6, 2024. Dr. Hoek was elected an international member in 2006 for major worldwide contributions in the development and application of rational design procedures for engineered systems in rock.

Lester A. Hoel, 87, L.A. Lacy Distinguished Professor of Engineering Emeritus, University of Virginia, died April 19, 2022. Dr. Hoel was elected in 1989 for outstanding contributions and leadership to urban public transportation research and education.

George M. Homsy, 80, affiliate professor, Departments of Mechanical Engineering and Chemical Engineering, University of Washington, died May 5, 2024. Professor Homsy was elected in 2006 for innovative experimental and theoretical studies of multiphase and interfacial flow phenomena and for the development of educational materials in fluid mechanics.

Ellis L. Johnson, 85, Coca Cola Professor of Industrial and Systems Engineering, Georgia Institute of Technology, died February 20, 2024. Dr. Johnson was elected in 1988 for fundamental contributions to discrete optimization and software design, and its practical applications to distribution and manufacturing systems.

Frank D. Judge, 77, retired general manager, Nuclear Operations, GE Nuclear Energy, died April 29, 2011. Dr. Judge was elected in 1988 for outstanding contributions to the development, understanding, and application of nuclear technology to naval reactor systems and commercial boiling water reactors.

Susumu Kato, 91, professor emeritus, Kyoto University, died January 18, 2020. Professor Kato was elected an international member in 1995 for contribution to atmospheric and ionospheric research and for leading the development and use of a major electronically sterrable VHF atmospheric radar.

William Kuperman, 81, director, Marine Physical Laboratory, University of California, San Diego, died June 30, 2024. Dr. Kuperman was elected in 2014 for international leadership in the development and application of computational methods for ocean acoustics.

Charles R. Kurkjian, 93, emeritus research professor, Rutgers, The State University of New Jersey, New Brunswick, died January 26, 2023. Dr. Kurkjian was elected in 1994 for contributions to the understanding of the strength and fatigue of glass that led to development of long optical fibers.

Yu-Kweng M. Lin, 100, Charles E. Schmidt Eminent Scholar Chair in Engineering (retired), Florida Atlantic University, died January 28, 2024. Dr. Lin was elected in 2000 for research contributions to the theory of stochastic dynamics and its applications to engineering structures.

John W. Lyons, 93, distinguished research fellow (retired), National Defense University, died March 14, 2024. Dr. Lyons was elected in 1985 for outstanding contributions to fire science and technology.

J. Ross Macdonald (NAS), 101, William Rand Kenan, Jr. Professor of Physics, Emeritus, The University of North Carolina at Chapel Hill, died March 30, 2024. Dr. Macdonald was elected in 1970 for leadership in research, development, and evaluation and personal contributions to electronic circuits and devices.

Alfred U. MacRae, 91, consultant, MacRae Technologies, died February 15, 2023. Dr. MacRae was elected in 2003 for advancing our understanding of ion implantation, its application to the fabrication of electronic devices, and its introduction into manufacturing.

Adolf D. May, 96, professor emeritus of civil engineering, University of California, Berkeley, died August 16, 2023. Dr. May was elected in 1990 for outstanding contributions to traffic management, especially optimal freeway operations and ramp control, and to transportation engineering education.

Charles J. McMahon Jr., 89, professor emeritus of materials science and engineering, University of Pennsylvania, died December 10, 2022. Dr. McMahon was elected in 1980 for contributions to the understanding and mitigation of grain boundary embrittlement of alloy steels.

Arvind Mithral, 77, Charles W. and Jennifer C. Johnson Professor, Massachusetts Institute of Technology, died June 17, 2024. Professor Mithral was elected in 2008 for contributions to data flow and multi-thread computing and the development of tools for the high-level synthesis of hardware.

Johannes Moe, 97, advisor emeritus, SINTEF, died September 19, 2023. Dr. Moe was elected an international member in 1977 for contributions to structural analyses and optimization with applications to wood and concrete construction and to ship and shell structures.

Arun N. Netravali, 76, managing partner, OmniCapital LLC, died November 4, 2021. Dr. Netravali was elected in 1989 for contributions to the art and science of image processing and communications and to the management of digital systems research.

Amos M. Nur, 86, Wayne Loel Professor of Earth Sciences and Professor of Geophysics, Stanford University, died June 10, 2024. Professor Nur was elected in 2001 for founding and establishing rock physics technology for quantifying rock properties from remote seismic measurements.

Marc J. Pélegrin, 100, honorary scientific adviser, (ONERA) Centre De Toulouse, died January 1, 2024. Dr. Pélegrin was elected an international member in 1978 for contributions in automatic control and in the advanced education of aeronautical engineers.

Donald E. Petersen, 97, chairman and CEO (retired), Ford Motor Company, died April 24, 2024. Mr. Petersen was elected in 1988 for outstanding leadership in the development of high-quality, smaller, lighter, more fuel-efficient, and more socially acceptable automobiles.

John R. Rice, 89, W. Brooks Fortune Distinguished Professor Emeritus, Purdue University, died January 7, 2024. Dr. Rice was elected in 1994 for leadership in founding the field of mathematical software and for fundamental contributions to its content.

Lubomyr T. Romankiw, 93, IBM Fellow, TJ Watson Research Center, died June 27, 2024. Dr. Romankiw was elected an international member in 2014 for innovation of thin-film magnetic head structures and electrochemical process technologies for microelectronics device fabrication.

Hajime Sasaki, 86, retired honorary advisor and former chairman, NEC Corporation, died June 21, 2022. Dr. Sasaki was elected an international member in 2000 for contributions and leadership in development of advanced very large scale integration (VLSI) systems and in growth and harmonization of the international semiconductor industry.

Charles D. Scott, 92, retired director, Bioprocessing Research and Development Center, Oak Ridge National Laboratory, died August 25, 2022. Dr. Scott was elected in 1986 for the development of advanced separation and processing concepts that have broad applications in the areas of biotechnology and nuclear energy.

Eugene Sevin, 95, independent consultant, died June 26, 2023. Dr. Sevin was elected in 1985 for technical contributions to the development of hardened protective structures that have materially increased the defensive capability of the United States.

William J. Spencer, 93, chairman emeritus, SEMATECH, died April 7, 2024. Dr. Spencer was elected in 1988 for pioneering contributions in the development of piezoelectric devices, innovative research in drug delivery systems, and leadership in microelectronics.

Dale F. Stein, 87, president emeritus, Michigan Technological University, died October 9, 2023. Dr. Stein was elected in 1986 for leadership in the science of deformation and the trace element embrittlement of metals, in engineering education, and in public and technology transfer.

Simon M. Sze, 87, honorary chair professor, National Chiao Tung University, died November 6, 2023. Dr. Sze was elected in 1995 for technical and educational contributions to semiconductor devices.

Chung L. Tang, 88, Spence T. Olin Professor of Engineering, Emeritus, Cornell University, died May 31, 2022. Dr. Tang was elected in 1986 for contributions in the field of quantum electronics, which include traveling-wave laser resonators and electro-optic modulators.

Charles E. Till, 89, senior counselor to the laboratory director, Argonne National Laboratory, died March 22, 2024. Dr. Till was elected in 1989 for leadership in fast-reactor technology development.

Theodore Van Duzer, 95, professor emeritus, University of California, Berkeley, died October 24, 2023. Professor Van Duzer was elected in 1997 for the application of superconductivity to high-speed electronic devices and circuits.

John B. Wachtman Jr., 94, professor emeritus of ceramics, Rutgers, the State University of New Jersey, New Brunswick, died December 13, 2022. Dr. Wachtman was elected in 1976 for contributions to the mechanical behavior of non-metallic materials through applications of solid-state physics.

William M. Webster, 92, retired vice president, RCA Corporation, died

December 14, 2017. Dr. Webster was elected in 1976 for contributions to the development of gas discharge and solid-state devices.

Andrew M. Weiner, 65, Scifres Distinguished Professor, Purdue University, died February 13, 2024. Dr. Weiner was elected in 2008 for contributions to the development of femtosecond optical-pulse shaping technology.

Invisible Bridges

Living in Viele's World

To make engineering more relevant and responsible, we must decode its politics of recognition.

Guru Madhavan is the Norman R. Augustine Senior Scholar and senior director of programs at the National Academy of Engineering. His new book is *Wicked Problems: How to Engineer a Better World* (W. W. Norton, 2024).

For generations, New York City engineers have consulted a hand-colored map of Manhattan's waterways from 1865, a masterwork that depicts creeks and canals, marshes and meadows in vivid shades of blue, green, and pink. If you want to know whether a property might flood, where ground might be unstable, or whether a basement is likely to fill up with water, the map has your answers. "A swell lithograph, long as a Buick," one admirer enthused. It was drawn by Egbert Ludovicus Viele, a West Point-trained engineer who wanted to pictorially explain the health risks of filling up the city's natural watercourses and diminishing natural drainage in the name of urban development. To that end, the Viele Map, as it's now known, showed the streams, swamps, pig sties, and shanties.

Before New York City became a metropolis, with its underground web of subways and utilities running under the bristles of high rises, there was Viele. His map is the informational substrate—the foundation—that made today's city possible. But outside the offices of urban planners and civil engineers, very few people know Viele's name. They don't know that he proposed the first subway for New York—the Arcade Under-Ground Railway—and supported the creation of the Board of Public Health. Or that he was deeply involved in building both Central Park and Prospect Park. If they do know of a foundational New York architect, it is Viele's rival, Frederick Law Olmsted, who is given full credit for designing Central Park. Olmsted's New York freezes the heart of the city in a bucolic pastoral, a kind of never-never land. By contrast, Viele's city is still growing—up, down, betwixt, and beyond. Viele's story is as much about how New York became New York as it is about the politics of recognition—how credit is assigned to engineers.

Viele became interested in the connection between sanitation, engineering, and health when he was a lieutenant during the Mexican-American War, sitting frustrated on the north bank of the Rio Grande while cholera killed more of his men than actual combat. At the time, miasma theory explained cholera as a product of offensive odors from rotting refuse. The British crusader Edwin Chadwick even envisioned a "pure air" solution, with tall tubes stretching into the heavens to draw fresh oxygen down for piped delivery to dwellings at a price. Viele was convinced that good sanitation could protect people from disease, and he later recounted his sense that topography, particularly places where water pooled, was driving infection.

Viele had a chance to test his ideas when he returned to New York in the mid-1850s. A few years earlier, New York City acquired a parcel of land, around 800 acres, through eminent domain. The space, to be turned into a park, would serve as the "city's lungs," with the belief that urban progress could enable social and moral growth. The task of converting that "cheerless waste into a scene of rural beauty," in the words of one historian, fell to Viele. He meticulously mapped the muddy land, pooling patterns, and underground streams of the purchased plots, which he described as "perhaps the most unpropitious that could have been selected for such a purpose on the whole continent."

This piece also appeared as a feature in the summer 2024 edition of *Issues in Science and Technology*.

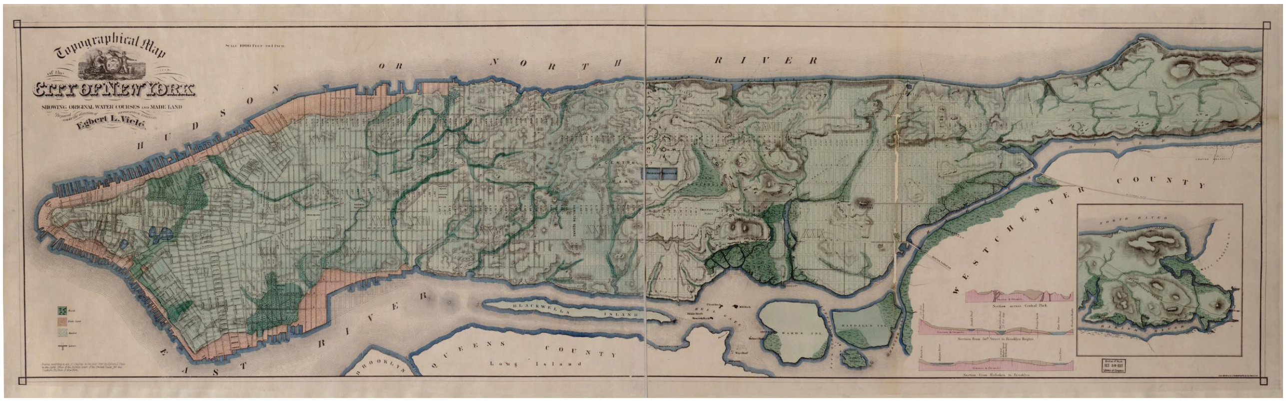
Inspired by the name of this quarterly, this column reflects on the practices and uses of engineering and its influences as a cultural enterprise.

As Central Park's first chief engineer, Viele emphasized drainage measures to ensure the park didn't turn into "a pestilential spot, where rank vegetation and miasmic odors taint every breath of air." He aimed to transform the low swamp into a grassy meadow with a new reservoir, a driving loop for carriages, a sports field, a military parade ground, a botanical garden, and winding trails. Viele's survey of both natural and installed drainage was detailed. He believed that his modern masterwork would rival the grand gardens of Berlin, Paris, and London, and still be completed under the allotted budget of $1.5 million. Viele's design, historian Jon Scott Logel notes, followed the maxim that "'the greatest art is to conceal art' through a mixture of 'the natural' and the 'artificial.'"

Months into construction, in September 1857, a dapper Frederick Law Olmsted walked past the job seekers lined outside Viele's shack office. Olmsted, an architect, carried an influential political endorsement as his letter of recommendation. Olmsted described himself as an "unpractical man" who valued "townsite consciousness," an urban design that privileged public parks for democratizing healthful air and light. In contrast, Viele believed combining the tools of organized water-waste sewerage and systematic sanitary surveys could promote hygienic environments. Their contrasting visions would both prove crucial to comprehensive city planning.

The two men were very different from each other. Olmsted was charming; Viele was crotchety. Olmsted's vision was cheery, while Viele's was weary. Olmsted was a Republican, Viele a Democrat—leading Viele to suspect that the city Republicans had planted Olmsted to derail his visionary proposal for Central Park. Viele silently glanced at Olmsted's letter in his office and ignored him for the rest of the day, dismissing him because he wanted a more "practical man." Yet Olmsted was persistent. Visits later, Viele gave him his first assignment. Olmsted would remember that moment where Viele "exhibited his practical ability by leading me through the midst of a number of vile sloughs in the black and unctuous slime of which I sometimes sank nearly half-leg deep."

General Egbert L. Viele



General Viele's map of New York

The city's political divisions were sharp, and Republicans wanted to curb the Democrats' influence over the project. The English-born architect Calvert Vaux convinced the park commissioners that Viele's design was mediocre and mundane, something one would expect from a mere engineer. Viele was ousted, his design dropped. Instigated by Vaux, the city sponsored a design competition for the layout of the park. Vaux paired up with Olmsted, and in April 1858, they won the contest and a $2,000 prize for their naturalistic Greensward plan, now referred to as the "Sistine Chapel of landscape design." Olmsted was appointed Central Park's chief architect, blending Viele and Olmsted's former duties as chief engineer and superintendent. Viele contended that Vaux and Olmsted stole his plan, and a court later ruled in Viele's favor and awarded him some $8,000. (Viele and Olmsted clashed again on the design of Prospect Park in Brooklyn, whose initial planning began under Viele in late 1860.)

An innovator who, for example, installs a "sheep meadow" in the middle of a metropolis receives many laurels and much praise— while those who do operations and maintenance fly under the radar of cultural recognition.

Viele's activism was motivated by his belief that the developers shouldn't ignore Manhattan's natural topography. In 1865, when the Citizens Association of New York campaigned for the creation of a Board of Health, Viele was a strong proponent. One of his maps even appeared in a report, described as "medical topography."

In the 1870s, Viele gained more influential positions, which he used to develop the Upper West Side and propose mass transit options using elevated railroads. And in 1883, to Olmsted's dismay, Viele became president of the Parks Commission that had once fired him. Olmsted grumbled that for 25 years, it had been Viele's "principal public business to mutilate and damn the park."

The design philosophies Viele and Olmsted championed, both vital for public health, offer insights into the politics of recognition evident across engineering—and how we as public and professionals assign prestige to one line of work over another. Viele and Olmsted were both agents of reform and in constant competition. The contrast in their design philosophies, however, alludes to a status game that still prevails in engineering today. An innovator who, for example, installs a "sheep meadow" in the middle of a metropolis receives many laurels and much praise—while those who do operations and maintenance fly under the radar of cultural recognition. Prestige is often mistaken for excellence, but it lands somewhat indiscriminately. As scholar Lewis Leopold wrote in 1913, "prestige … throws its cold electric glitter on strong and weak, useful and useless, good and bad, true and false, beautiful and ugly alike."

The politics of prestige determine how society assigns fame, manufactures eminence, propagates popularity, and ultimately judges one individual over another. "Due recognition is not just a courtesy we owe people. It is a vital human need," notes scholar Charles Taylor, pointing to how identity is partly shaped or misshaped by the presence or absence of recognition. But this dynamic also subtly shifts how and what gets remembered about the world, causing society to overlook promising opportunities for the future. In engineering, the status accrued by high prestige may end up depriving society of visionaries who see the potential in building sewers and draining swamps to create better lives for all.

But there is more to be gained from the contrast between Viele and Olmsted. Viele envisioned a city that might grow willy-nilly but in which peoples' lives could be improved by sanitation, by subways and elevated trains, and canals. He lived in the real world—a working city with unruly aims and desires. Olmsted wanted to create a planned city with an orderly hierarchy of nature and commerce. It was a fantasy of pastoral hygiene—a contradiction that was at once idealistic and unrealistic for a polyglot city. In essence, Olmstead imagined a city crystallized around a park where time stopped before the Industrial Revolution. Viele's New York was a protean space, relentlessly renovating and reconfiguring around its inhabitants and their needs. Today, the world may admire and amplify Olmstead's vision, but New Yorkers live in the city that Viele imagined.

"It is a difficult matter to persuade people to look forward to the comfort of generations to come after them, when they have to furnish the means for it," Viele wrote in 1860. “And nothing is so essential to the success of a system of sewerage, as to make it sufficiently extensive and comprehensive in the beginning.” Viele’s forward-thinking work connected the built environment—improved drainage and public works—with promoting health-conscious behavior. He also urged a kind of self-sacrifice for future generations; investment in the lives of those who come after. “In this sense,” Logel observes in his history of New York City’s design, “Viele was a precursor to the progressives who emerged in the last two decades of the nineteenth century.” The persistent usefulness of Viele’s map should inspire investment in the kind of foundational, life-sustaining engineering that benefits everyone.

Between 1861 and 1863, Viele served in the Union army as a military governor in Virginia and commanded Civil War campaigns in Georgia and South Carolina. Although his service seems to have been unexceptional, in later years he waxed poetic about his experience accompanying Abraham Lincoln to a battlefield, prompting listeners to wonder if he was actually a Republican. Viele described the president as “kind, genial, thoughtful, tender-hearted, magnanimous,” with whom he enjoyed the “very closest intimacy” during his “wonderful fund of reminiscence and anecdote.”

Viele later became a congressman, but he felt he never got the public recognition he deserved. He ordered for himself a 31-foot-tall pyramid tomb with columns and sphinxes—then the largest in the West Point cemetery. Paranoid about the prospect of being buried alive in his marble coffin, he had a buzzer installed so he could get help if needed. It was never used, except by some pranksters.

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