Innovative Partnerships for the Future: NSF Industry Partnership Summit

Workshop Report

Workshop Report

Host

National Science Foundation

Organizer

UIDP (uidp.org)

About UIDP

UIDP is a solutions-oriented, global forum where academic and industry representatives find better ways to work together. Our membership, comprising top-tier innovation companies and world-class research universities, identifies issues affecting university-industry relations and seeks new approaches to partnership and collaboration. Together, we produce tools and resources to help members make a greater impact. We don't just talk about problems. We solve them.

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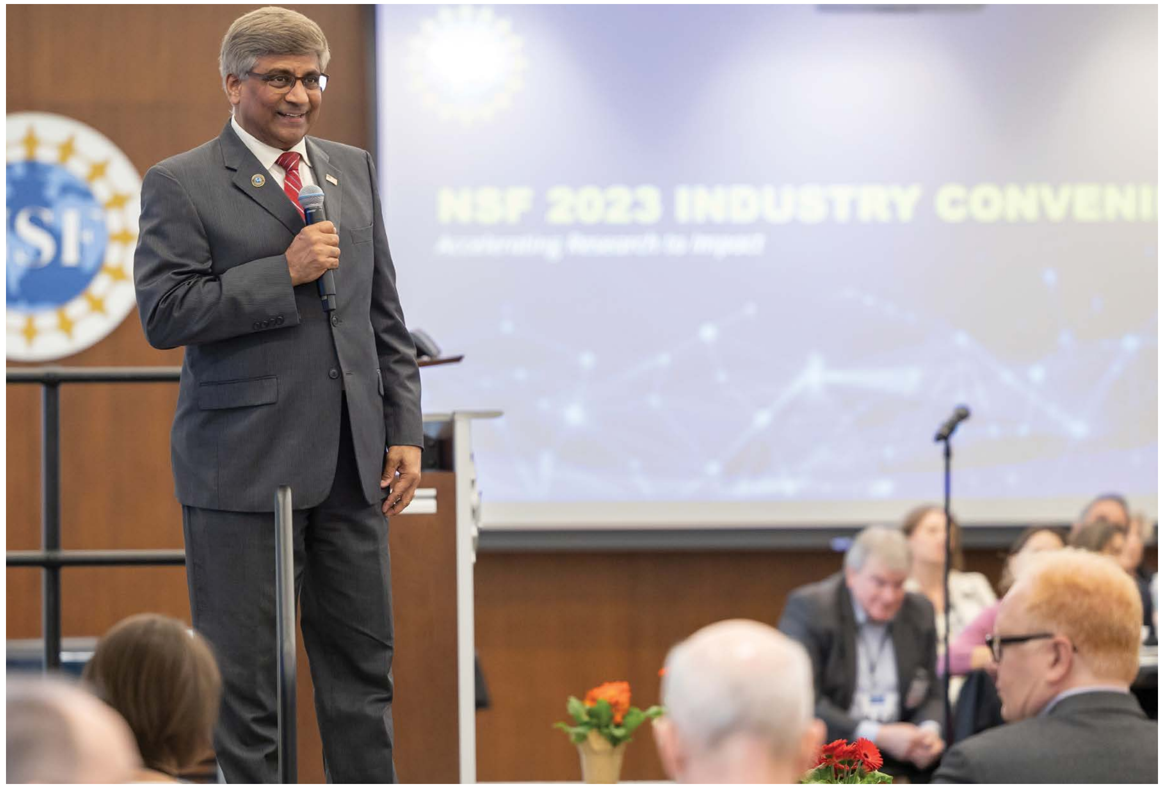
"The U.S. National Science Foundation has been at the forefront of piloting new approaches to multi-sector public-private funding models," said NSF Director Sethuraman Panchanathan. "In order to maintain our leadership position globally, we must continue to shape effective strategies for partnering across research, workforce development, and infrastructure and explore additional opportunities to expand public-private partnerships."



Sethuraman Panchanathan, NSF Director. *Credit: NSF*

Executive Summary

In April 2023, a convening was held at the U.S. National Science Foundation, bringing together 63 science and technology leaders representing 49 leading companies, to engage in cross-sector discussions about best practices for public-private partnerships. The event included representatives from NSF's directorates to provide information on research areas of interest and facilitate discussion about partnership challenges and opportunities, key technology focus areas ripe for co-funding, and workforce development and training opportunities for growth.

There were three key objectives for the NSF Industry Partnership Summit:

Strategy Development. Shape effective strategies for partnering across research, workforce development, and infrastructure—explore opportunities to expand public-private partnerships and characteristics of new funding modalities.

Sector Interest. Identify several "coalitions of the willing," or companies in a sector highly interested in pursuing deeper discussions on partnership opportunities in research or workforce development.

Greater Engagement. Expand industry awareness of the opportunities for public-private partnerships to accelerate research and workforce development.

KEY FINDINGS

Increase industry participation in NSF efforts. One overarching need is to expand the number and size of companies that co-invest with NSF in funding opportunities. Small to medium-sized companies and startups offer valuable use cases, facilities, and technical capabilities, but lack resources internally to support ongoing engagement, such as project managers and partnership officers. An NSF resource to assist with coaching and simplification of processes could make broader participation possible.

Develop new IP approaches. Funded research can lead to new discoveries, and the intellectual property (IP) emanating from research can create opportunities for potential development if the pathway to commercialization is transparent, rational, and not needlessly complex. NSF has developed approaches that work, but new models are needed for companies to partner at different investment levels, including new IP management approaches. Models are also needed that recognize tangible, non-monetary contributions such as facilities, use cases, and other in-kind assets as co-investment options. Selecting from a menu of approaches and options from the start would simplify decision making for companies that desire to collaborate.

Move faster. There is a need to reduce the timescale for NSF engagement (from idea to solicitation) and to reduce the paperwork burden so industry can more easily collaborate with NSF. One option is to consider co-funding pilot programs with the option to scale and increase investment at the three to six-month mark.

Improve communication. Regular, industry-facing communication from NSF is needed to inform companies about opportunities to meaningfully engage in research activities. There is also a need for an NSF web presence specifically for industry partners (and potential collaborators).

Facilitate greater connectivity. Participants desire regularly established meetings that bring industry representatives together to share challenges and identify solutions, segmented by technology interest area. Meeting with NSF program managers that align with research interest areas could offer opportunities for industry representatives to help inform and shape future funding opportunities and build informed technology roadmaps.

Strengthen experiential learning opportunities. For workforce development, find ways to connect NSF-supported researchers and Ph.D. students with experiential opportunities in industry. Upskilling through non-degree coursework, certifications, and practicum experience offers additional ways to expand the talent pool.

Fund work closer to industry research interests. To make the transition to translational research, support projects at the technology readiness level (TRL) of three or higher.[1]

Create onramps for new partners. Approaches that allow for additional companies to join projects after initial funding rounds would allow more companies to participate, perhaps at lower funding levels if offering in-kind value (use cases, test beds, etc.).

Advance soft-skill capabilities. Design thinking, communication, and multidisciplinary team dynamics are workforce needs that should be emphasized alongside technical skills in both academic and experiential learning.

Raise researcher awareness. Support engagement with academic researchers so they understand the value of use-inspired and translational research and how it relates to economic growth.

Develop support tools. A co-investment model involving industry and NSF could be leveraged to stand up tools that could be used across an industry sector, e.g., data standardization and platforms, digital twin capabilities, etc.

Cultivate multi-agency work. Engage in multi-agency (and multinational agency) funding for technology development in grand challenges to pool more resources and accelerate progress.

Background

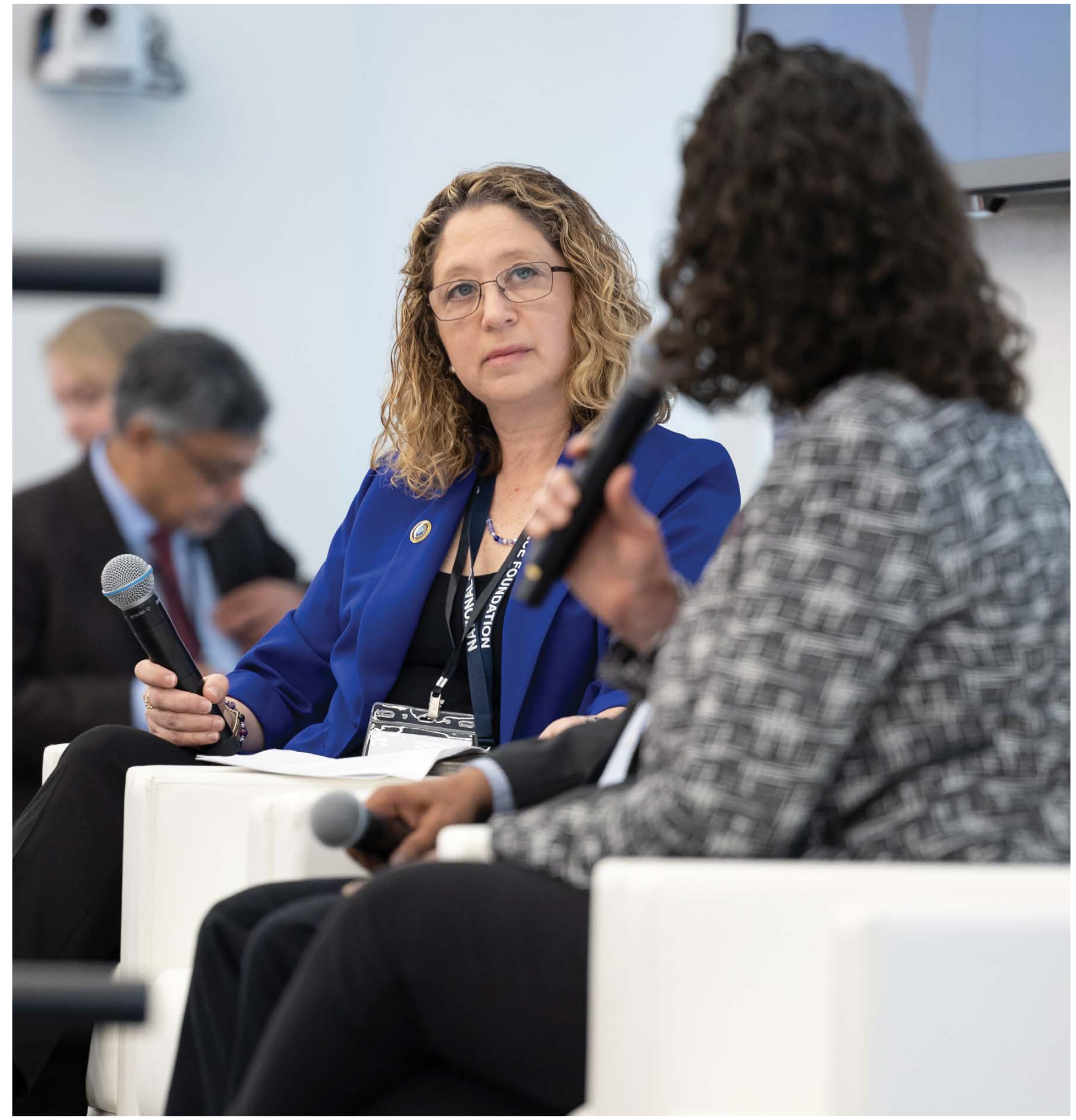
NSF has historically supported investigator-driven, primarily academic research teams on projects funded through directorates within disciplinary verticals (e.g., biology, engineering, mathematics and physical sciences, computer and information science, geosciences, social and behavioral sciences). With varying and mostly complementary motivations, companies have worked independently to sponsor academic research. As the private and public sectors seek to address contemporary global challenges requiring science and technology solutions, cross-sector, joint research collaborations are gaining prominence.

NSF has sought to work more closely with companies to co-fund and launch research efforts through the NSF solicitation process in areas such as workforce development, artificial intelligence, and semiconductors. In recent years, companies and other non-academic research institutions have taken on the lead role in NSF funding awards themselves, including projects funded through the Convergence Accelerator program and the recently announced NSF Regional Innovation Engines Development program awards. Companies have also co-invested with NSF in areas of mutual interest beyond research, such as the partnership between Boeing and NSF's STEM Education Directorate (EDU) to invest in curriculum design and deployment and to reskill and upskill the STEM Workforce.

In the United States, NSF has been at the forefront of piloting new approaches to multi-sector public-private funding models. Examples of NSF utilizing direct partnerships with one or more companies to fund solicitations to solve industry-scale R&D problems include the NSF/VMware Partnership on the Next Generation of Sustainable Digital Infrastructure (NGSDI), many of the National Artificial Intelligence (AI) Research Institutes, the Resilient & Intelligent NextG Systems (RINGS), and partnerships with Ericsson, IBM, Intel, and Samsung to support the future of semiconductor design and manufacturing (part of the new Future of Semiconductors [FuSe] initiative). Each of these partnerships has been conceived, developed, and negotiated individually, and the process and timeline from idea to release of a solicitation are, at times, long and complex. There is much to gain by streamlining and democratizing the research partnership process to engage more companies and nonprofits and expand the breadth of joint funding opportunities.

NSF TIP Directorate Mission

The Directorate for Technology, Innovation and Partnerships (TIP) harnesses the nation's vast and diverse talent pool to advance critical and emerging technologies, address pressing societal and economic challenges, and accelerate the translation of research results from lab to market and society. TIP improves U.S. competitiveness, growing the U.S. economy and training a diverse workforce for future, high-wage jobs.



Gracie Narcho, NSF Deputy Assistant Director for TIP. *Credit: NSF*

In March 2022, NSF announced the launch of the Directorate for Technology, Innovation and Partnerships (TIP), its first new directorate in 30 years. Building on the agency's 75-year commitment to U.S. innovation and curiosity-driven research, TIP was created to advance promising new technologies and accelerate translation of research outcomes from the lab to the marketplace, with ambitious overarching goals: addressing global-scale societal and economic challenges, improving U.S. economic competitiveness, and training a ready workforce.

Leveraging R&D partnerships across government, academic, and industry sectors is central to TIP's purpose. TIP was created to broaden research collaboration and to open new opportunities to leverage aligned interests, market intelligence, and technical expertise with companies, nonprofits, higher education institutions, and state, local, and international governments.

The CHIPS and Science Act, signed into law on Aug. 9, 2022, ushered in new opportunities for the American research and innovation enterprise to accelerate progress in key technology areas. It brought new focus to science and technology translation—the application of key research outcomes to develop science-based solutions. Translational research has typically been the purview of industry, which invests in research as a means to accelerate progress in technology innovation and advance market-based priorities. The CHIPS and Science Act included authorization for the NSF TIP Directorate and put forward specific activities, including advancing novel approaches and reducing barriers to the development of products and services to advance the human condition. It also called on TIP to develop new frameworks for academia, industry, nonprofits, and venture capital companies to pursue commercialization together.

Recognizing the opportunity, NSF TIP seeks ways to optimize the process of prioritizing timely and pertinent topics, identifying potential partners, and structuring collaboration modalities to increase efficiency and maximize impact. The NSF Industry Partnership Summit provided a forum to identify cross-sector research needs, analyze gaps and barriers to partnership, and begin to develop a menu of standardized approaches to move the partnership process forward efficiently. In addition, the summit sought to raise awareness and broaden participation by companies (in number and in more sectors) in NSF-organized solicitations with an ambitious goal to catalyze research with societal-level impact.

To foster innovation and technology growth, TIP catalyzes collaborations in its own programs, such as the Convergence Accelerator and the Regional Innovation Engines programs, but it also seeks to advance cross-sector partnerships and their translational outputs across all NSF directorates and in all fields of science and engineering. The overarching goal is to foster development of new technologies and new industries while engaging a largely untapped talent pool with the ability to help shape new approaches in areas like artificial intelligence (AI), advanced manufacturing, advanced wireless, biotechnology, quantum information science, semiconductors, and microelectronics.

NSF's interests in advancing research and commercial development to benefit society are spearheaded by TIP and occur at a crucial time in the context of U.S. innovation across all fields of discovery and all sectors of the economy. The pace of discovery is rapidly accelerating as machine learning and AI leverage large data sets to open new avenues for discovery. Global competition is on the rise, along with increasing recognition that technical solutions hold the promise to address major societal challenges. At the same time, the United States must engage and activate diverse voices to meet its economic goals; future growth and development must include the "missing millions" in terms of geography, experience, and demographics. There is a pressing need to skill and re-skill a technical workforce to meet the demands of an increasingly technology-centric economy.

NSF has forged a number of fruitful public-private collaborations with industry that have resulted in jointly funded research activities. While it is an attractive time to explore modalities for increasing private sector participation in federal research initiatives and bolster efforts with high-impact results, to do this, new approaches and strategies must be developed that are attractive to companies, agencies, nonprofits, and academia, and advance their missions.

Catalyzing a Paradigm Shift: The NSF Industry Partnership Summit

On April 26, 2023, at NSF's headquarters in Alexandria, VA, the University Industry Demonstration Partnership (UIDP) convened a meeting of science and technology leaders representing companies with significant R&D spending, as well as nonprofits that invest in technology research (see the attendee list in Appendix A). Attendees actively participated in discussions to identify how industry could better engage in public-private partnerships—in previously tested and new ways—to foster vibrant innovation growth through highly collaborative, multi-sector funding programs that support use-inspired and translational research. Importantly, while the meeting was supported by TIP, in keeping with its mission of serving as a crosscutting directorate, all NSF directorates and offices participated.

NSF Assistant Director for TIP Erwin Gianchandani opened the summit with an overview of NSF's role in funding the nation's public research enterprise and TIP's imperative to accelerate research impact through industry partnership. To rapidly expand partnership opportunities, new, effective ways to structure government funding programs are needed to increase industry engagement in a fair and efficient manner. The assembled research leaders from industry were uniquely positioned to identify actionable steps to raise awareness of and increase participation in future public-private collaborations. As the public and private sectors seek to accelerate breakthrough technologies and address contemporary global challenges, joint research partnerships are the preferred avenue to strategically leverage expertise and resources and achieve mutually beneficial R&D goals.

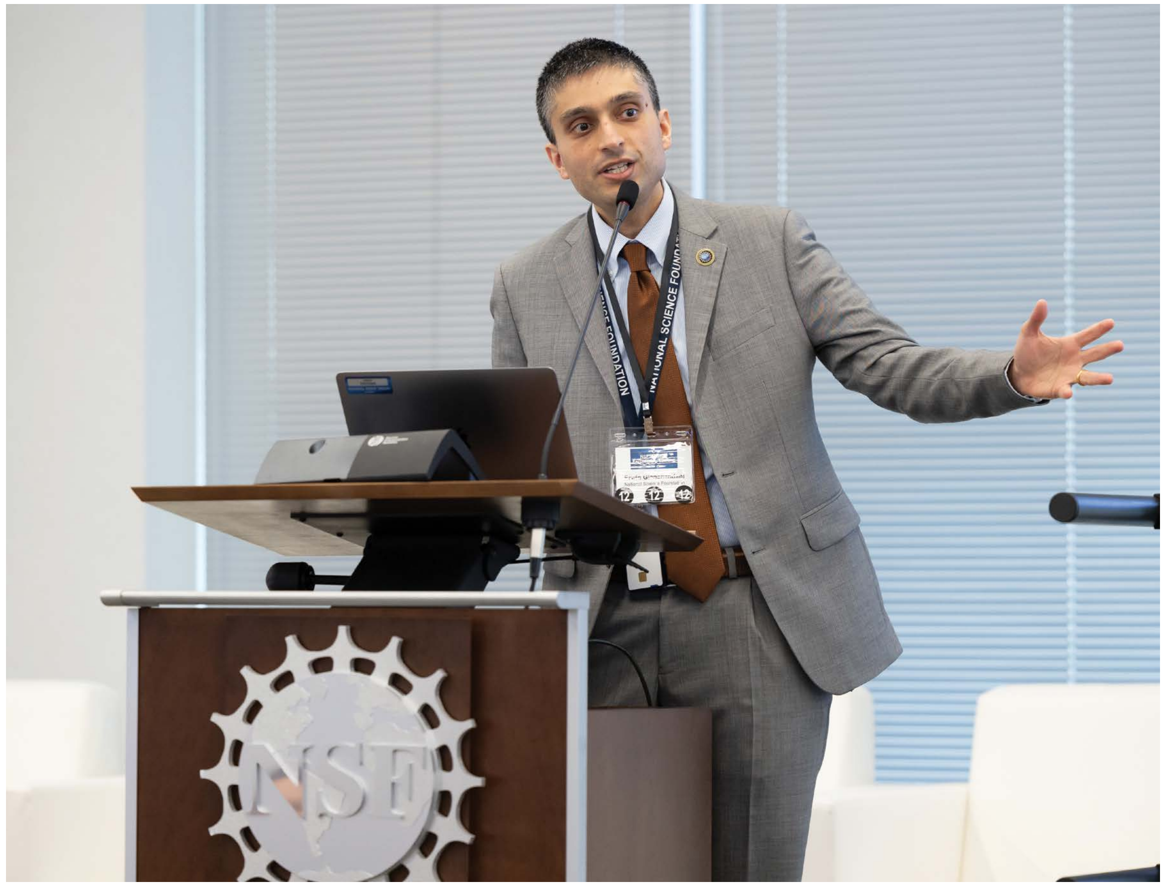
Companies possess an inherent interest in leveraging their dollars and diffusing risk in emerging research areas through co-funded research in collaboration with the federal government. Co-funded research offers companies the following:

- Access to a broader, more diverse pool of academic researchers;
- A resource multiplier effect when partnering with NSF and other companies on pre-competitive research;
- The opportunity to build strong connections to academic researchers and a future workforce of student researchers specializing in areas of interest to the company; and
- Credibility inherent in partnering with NSF and aligning with its well-regarded merit review process.

Industry involvement in co-funded programs increases the likelihood that publicly funded research outcomes will be applied to develop products and services that serve society. Additionally, industry offers market insights, useful connections, and additional support for academic investigators to pursue fruitful research (such as specialized equipment, novel data sets, or supplemental funding).

Although program structures vary, NSF has successfully partnered in the past with private entities through two broad modalities:

Catalyzed approach: The traditional and well-established vehicle is for a group of organizations (academic, corporate, nonprofit) to form a consortium to respond to a funding opportunity. An example is the Industry-University Cooperative Research Centers (IUCRC) program. Each center involves multiple partners that focus on a topic of mutual interest and help shape research directions. IUCRCs help accelerate the pace of innovation with multi-sector partnerships from academia and industry.

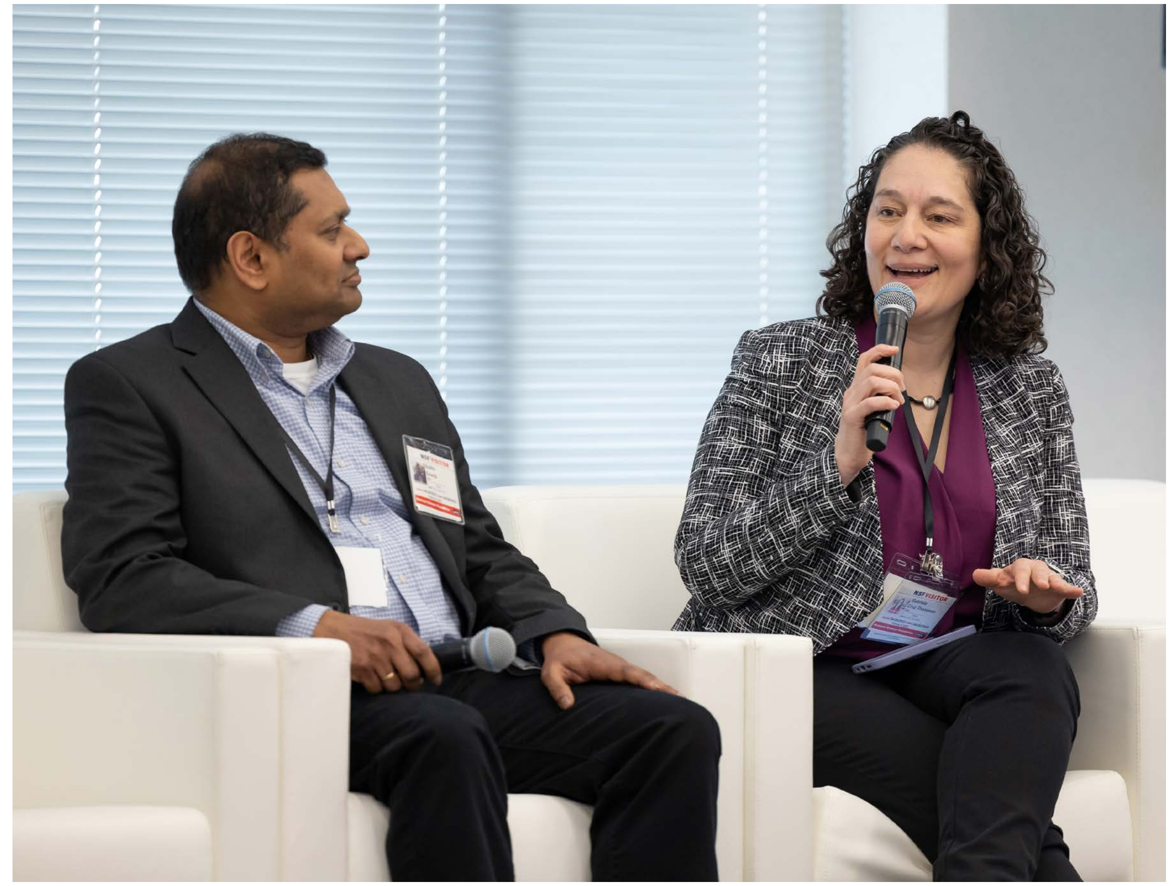


Erwin Gianchandani, NSF Assistant Director for TIP. *Credit: NSF*

Direct partnerships: Industry works with NSF to shape and distribute funding opportunities. One or more companies work with NSF to jointly identify research areas and commit resources to establish a funding program, and then academics pursue funding through the NSF solicitation process. Examples of direct partnerships include the NSF/VMware Partnership on the Next Generation of Sustainable Digital Infrastructure (NGSDI) program, the Resilient & Intelligent NextG Systems (RINGS) program, and the multi-company partnership with Ericsson, IBM, Intel, and Samsung to support the future of semiconductor (FuSe) design and manufacturing.

Direct partnerships allow NSF and companies to leverage external funding sources to support research in areas of societal importance. To date, this approach has proved most viable for research areas in the computational sciences that are pre-competitive and of broad societal-level importance. Broadening the topics for direct partnership beyond this particular research domain is appealing as it would extend the benefits of direct partnerships to more areas of research and more companies.

In addition to NSF programs that expressly involve industry partnerships, TIP is establishing a Strategic Partnerships Hub to connect the whole of NSF with prospective partners interested in supporting STEM research and workforce development. Each of NSF's directorates briefly presented their research priorities and examples of partnership opportunities in which industry could play a role.



Sudhir Gowda, IBM Research; Gabriela Cruz Thompson, Intel Labs. *Credit: NSF*

Panel: Current Models of Collaboration

Key insights in the direct partnership modality were provided by three current NSF partners. Gracie Narcho, NSF deputy assistant director for TIP, led the discussion with Sudhir Gowda, director, academic research programs, IBM Research; Gabriela Cruz Thompson, senior director of university research and collaboration, Intel Labs; and Chris Ramming, senior director of research and innovation, VMware. All three companies have a decades-long commitment to collaborating with academic partners to conduct fundamental research in high-tech topics. Intel alone invests $75 million annually in its academic partnerships.

Industry Motivations. Panelists said they derive tremendous value from partnership with NSF. First, NSF vastly expands any single company's reach to engage with researchers in U.S. universities, and NSF solicitations reach a strong network with deep scientific expertise. Additionally, NSF co-funding allows industry to expand the diversity of ideas and solutions to technical challenges.

NSF Role. As the largest federal funder of academic research, NSF possesses a unique convener and facilitator role with research solicitations representing diverse perspectives and extending the nation's ability to tackle industry-wide problems. In complex, multi-sector research areas such as cloud computing, NSF can convene complementary aspects of the ecosystem to ensure different points of view have a voice in shaping the research solicitation. Once proposals are submitted, its well-respected and neutral proposal review process is considered the gold standard for fairness.

IP Treatment. The panelists represented experience with a number of NSF partnerships and noted that IP management has not been a significant barrier; project topics are primarily pre-competitive and IP protection is less of an issue in the research areas pursued. Industry seeks guardrails that emphasize a company's freedom to operate. For NSF-industry joint efforts, the most common vehicle for managing IP is through a non-exclusive royalty-free license (NERF). Other models, such as public dedication of IP, can play an important role in certain situations.

Public Dedication of IP

Rather than focusing on ownership and licensing rights, public dedication of IP models seek value through the scholarly, technological, and ultimately societal impact of project results. Most often used in the high-tech realm, public dedication of results or IP generated by academic and corporate collaborations may be a viable and desirable outcome for both parties, while offering positive impact and benefits to the public. In an industry-funded project using a public dedication of IP approach, the parties agree to some or all of the following:

- They will not file patents on the results of the research;
- They will place appropriate public dedication/public domain markings on copyrightable results; and
- They will make results publicly available.

In some instances, explicit agreement by the parties that the project, or its result, is being undertaken primarily for societal benefit is intended to maximize immediate access and use by the public. This approach doesn't prevent partners from any IP arising from development of commercial products, but removes barriers.

Opportunities and challenges in partnering

Event participants joined smaller discussion groups to respond to a series of questions designed to uncover barriers and discover areas where partnership with NSF would help them meet organizational objectives in research and workforce development.

Perceived Barriers

Pace and cadence. The time horizon for industry-based research—from idea to research commencement—can be a few months, but the timeframe for NSF to go from topic selection to solicitation release is much longer. Moreover, companies work on a budget-year cadence of planning and allocation that may exclude them from participating in NSF research co-funding when calendars don't align.

IP issues. Translational research can fall outside the bounds of pre-competitive research, requiring models that give industry enough incentive to co-invest through licensing or other vehicles. IP issues complicate negotiations and can delay or disengage companies from participation.

Lack of partnership models suited for mid-size and smaller companies. Very large companies can engage more easily with NSF because they have infrastructure in place and can budget ahead for long-term (three- to five-year) partnerships. Small companies can access SBIR funding to expand translational research, but companies in between the very large and very small ends of the spectrum do not have a viable partnership vehicle at this time.

Administrative burden. Examples include the cost of tracking cost share, compliance with regulations, export control management, and perceived reputational risk if a company is audited and found out of compliance.

Infrastructure challenges. Company representatives had questions about staffing required to deploy partnerships and maintain engagement. There is high interest from industry in direct involvement with researchers during and post-award, but prior and current experiences demonstrate that this requires dedicated staff.

Lack of recognition for in-kind company contributions. Lab space, equipment, expertise, and translational use cases bring value to research partnerships but are not recognized in current NSF models.

Multinational issues about engaging with NSF. Many multinational companies, including non-U.S. ones, have a strong U.S. presence. The process to engage with NSF as a non-U.S. entity is perceived to involve an additional administrative layer. The optics of NSF co-funding with non-U.S.-based companies are also a challenge for risk-averse organizations.

Difficulty finding the right point of entry to engage. There is a wealth of information on the NSF website, for example, but it is not easy for industry to find current opportunities, information on partnering approaches, and points of contact.

Effort required to respond to an NSF opportunity. Leading or participating in the development of a full proposal response can overwhelm companies, which typically do not have personnel for this task.

Controlled unclassified information (CUI) can be a barrier to partnering in the national security space. Materials that fall under the CUI umbrella, although unclassified, require special handling and controls over dissemination, which creates additional complexity when partnering for research.

Strategies for NSF to Enhance Industry Partnerships

Engage industry earlier in the process. Companies know the challenges of taking research across the "valley of death" to commercialization and can help NSF-supported projects get across the finish line.

Research topics should be broad and scalable. Garnering greater industry participation is possible when industry supports pre-competitive, industry-wide priorities rather than narrow research topics.

Bring together multi-agency partnerships and promote silo breaking. Particularly for complex issues, NSF can broker opportunities for transdisciplinary research in developing technologies "at the edges" in collaboration with other agencies.

Build communities of interest around topic sets using a request for information (RFI) approach, with NSF serving as an anchor and convener.

Fund more mature topics at higher technology readiness levels (TRLs). This is an area where industry can help guide the process.

Drive moonshots. Think big and explore big challenges that meet a critical need. Consider creating ecosystem maps around key technology areas to identify different sectors that need to be involved.

Re-imagine IP strategies. Sometimes IP ownership is not the main issue; it's access, and sometimes within a narrow field of use. Industry may simply want the first right of refusal rather than directly owning IP.

New Models for Collaboration

Allow industry to take the lead and apply for NSF program funding in partnership with academia more often. The vast majority of NSF funding programs are aimed at academic researchers only. This would raise awareness, build trust, and introduce new companies to the concept of co-funding down the road.

Communicate through channels that industry monitors, e.g., place solicitations in the Federal Register in addition to releasing through typical NSF channels.

Create a single online presence where industry can connect with points of contact for programs seeking industry participation. Notably, NSF has already taken this step based on this feedback at the convening.

Simplify the process to engage in partnership with NSF by reducing paperwork requirements. For example, shift some steps from the application to the award phase.

Create onramps for additional partners. There is an opportunity to engage companies that were not involved in the initial round of funding a joint solicitation but can contribute later – both financially at a lower level than foundational investors or offer in-kind value (test beds, test cases, etc.) as a project progresses.

Identifying Technology R&D Interest

In establishing the TIP Directorate, Congress identified 10 broad technology focus areas for investment as a means to advance U.S. competitiveness through translational research. Summit participants represented companies with a range of specific technology interests that align with one or more of these areas. For the next set of breakout discussions, participants were grouped by area of technology interest to enable conversation around specific research directions companies would be interested in pursuing. Because a ready, skilled workforce is essential for companies to innovate and flourish, the discussion also elicited current needs for education, training, and development.

Technology Research Priority Areas Identified by Participants

Pursuit of the digital thread: Digital engineering, digital twinning, etc. Industry seeks tools to design once and prototype once through improved predictive testing.

Power management solutions for vehicles and large equipment.

Interactive data and standardized data across sectors to enable multidisciplinary research in different areas, from manufacturing to chemistry. This is essential to enable new capabilities in AI and machine learning (ML) that can rapidly accelerate research.

Technology advances to meet sustainability targets: Decarbonization, sustainable water use and reuse, and materials biodegradability are broad areas.

Biosciences topics research: Gene therapy and gene editing, microbiome research, small-molecule therapeutics, mRNA applications, robotics automation.

Shared data standards and open access platforms: Data standards and shared data platforms are needed to accelerate research in areas that do not currently share foundational data, such as chemistry (polymers, biodegradability, etc.).

Enhanced computing power, data storage, and advanced communications capabilities that move innovation to implementation and application are needed across a range of technical areas (e.g., robotics, AI, energy, biotechnology, and semiconductors).

Although participant groups discussed specific technology ripe for new research investment, there was also lively discussion about ways NSF **could create resources and environments for innovation to advance more rapidly**. The ability to test new ideas in instrumentation across the development lifecycle using sophisticated simulation was one example of a capability where NSF could invest that would provide benefit across the industry and de-risk innovation in niche market areas.

Participants noted that the CHIPS and Science Act and its vision for NSF and TIP to focus on later-stage technology development and deployment is still "news" to industry. NSF is much better known for its considerable investment in foundational research over the years, and companies still see it in those terms. Academic researchers are also accustomed to NSF funding for basic research. NSF can better communicate with academic researchers so they recognize the value of translational aspects of their body of work and how scaling use-inspired research can boost the economy.

One recommendation was for NSF to **co-invest in data standards, platforms, and tools to support industry collaboration** in a cost-share model to accelerate technology development for a given industry sector. This would also enhance multidisciplinary innovation efforts. Today, multidisciplinary teams may experience significant differences in how research is conducted. For example, biologists have made open access to data and data archiving a standard practice, but this is not the norm for chemists. Data standards and shared data platforms are needed to accelerate research in areas where this is not yet the norm. Shared tools could also fill in the gaps in manufacturing research that individual companies are not positioned to undertake on their own. Participants recommended **leveraging innovation hubs with an academic footprint or the new NSF Regional Innovation Engines** for this purpose.

As a pivot from NSF's practice of funding individual researchers and their highly focused projects, participants saw value in NSF convening company representatives in the same sector for **workshops to roadmap specific technology development topics**, including timelines and tangible expectations for deliverables. This is already a practice in some NSF technology areas (e.g., cybersecurity, AI, and data science). Just days after the NSF Industry Summit, the TIP Directorate released a request for information for technology roadmap development for its 10 key technology areas.

Participants expressed serious concern about having adequate programs to train or upskill current employees and recommended new **programmatic emphasis on community colleges** to fill this gap. Another workforce gap is the dual-skilled workforce. To fully leverage emerging capabilities in AI and to expand applications in quantum technology, there is a critical need for talent with cross-disciplinary expertise, such as physicists with computer science skills and chemists with data science skills. There is fierce competition in industry to recruit cross-trained, dual-technology candidates in fields such as quantum technology, biotechnology, and advanced materials.

Although there was broad interest among the companies represented in increasing workforce diversity, the STEM talent coming from universities does not currently provide an adequately diverse pool of candidates. Attracting new talent to smaller communities poses an additional burden; this affects manufacturing enterprises that operate in non-metropolitan areas in particular. Representatives recommended building excitement about STEM at the K-12 level to feed the talent pipeline for the long term. In the short term, Ph.D. programs would benefit by **expanding experiences beyond the academic research bench** through funding support for more student experiences in industry, as well as direct programmatic support for entrepreneurship and technology translation.

Partnering for Workforce Development

Breakout discussions focusing on workforce development delved more deeply into avenues to enhance training and recruitment. The participants noted the undeniable gap between companies' desire for a diverse workforce and the lack of diversity in the overall STEM talent pipeline. Industry is investing heavily in diversity programs but has not seen the desired outcomes; partnership with NSF in this area would be welcome at the associate, baccalaureate, master's, and doctorate levels.

A number of ideas were put forward for enhancement or further investment. Mentorship provides an opportunity for industry researchers to interact directly with promising talent. NSF may consider modeling a mentorship program on the UK STEM Ambassadors program. Participants said it is important to make participation easy for working-age industry representatives (not only retirees) to participate in these programs. Avenues and resources for reverse mentorship would also be valuable for industry.

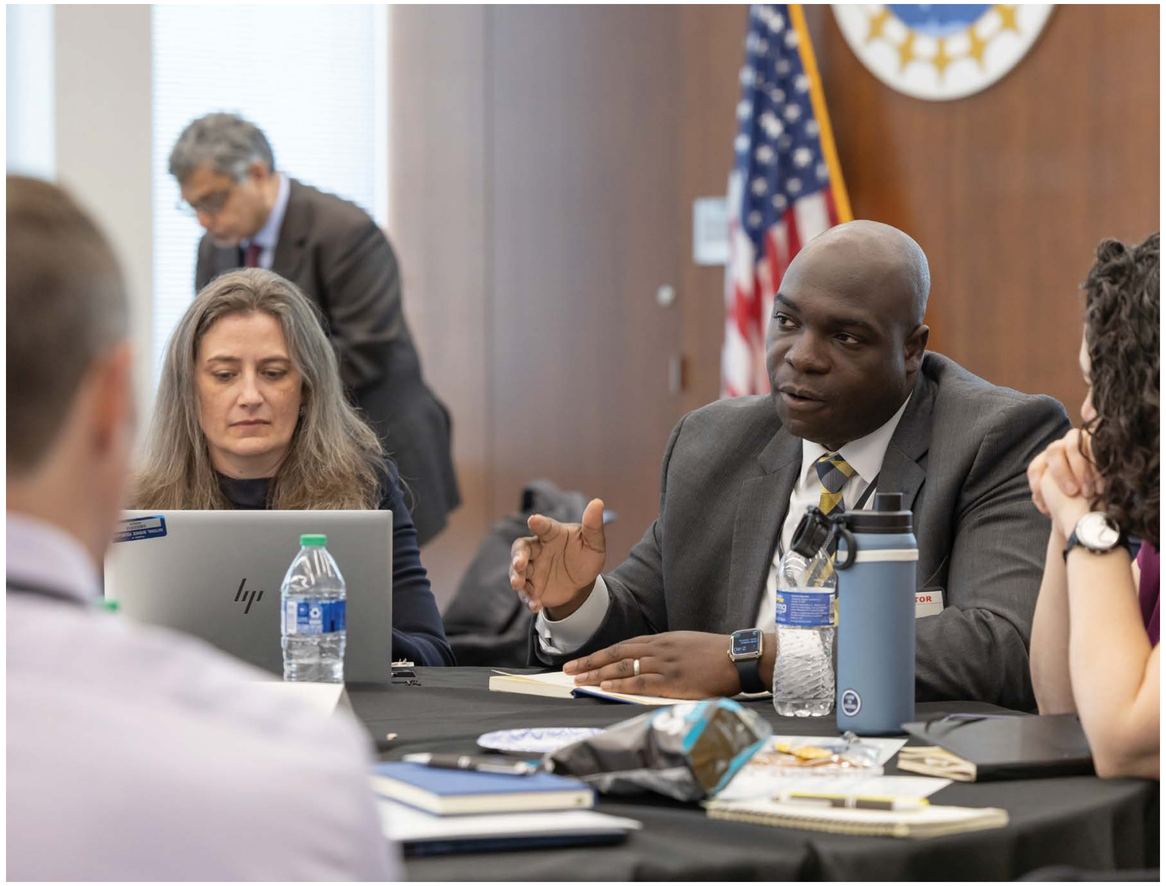
UK Research and Innovation STEM Ambassadors Program

Funded by UK Research and Innovation, this program connects volunteers from industry to serve as mentors to students at the request of teachers and youth leadership groups. The program provides training and serves as a central hub to match volunteers with opportunities to speak or connect with young people to inspire them to pursue STEM degrees.

Companies are eager to expand opportunities for promising students to gain practical experience in industry, such as internships and apprenticeships. A well-managed and maintained national online matchmaking portal for industry to identify candidates (and for faculty and students to find opportunities with industry) would serve to expand the talent pool.

There is also a need for faculty to spend time regularly in industry—especially in rapidly evolving areas like cybersecurity, AI, and machine learning—to ensure that curriculum stays up to date and students graduate with needed skills. The NSF Grant Opportunities for Academic Liaison with Industry (GOALI) funding offers opportunities for industry-academic interactions, but it is not visible enough and is underutilized. Funding for industry to co-design curricula with academic partners would greatly enhance workforce readiness.

Workforce development is an important element in NSF's desire to broaden engagement as well. Participants noted the need to expand the NSF Non-Academic Research Internships for Graduate Students (INTERN) program and to develop other opportunities to train more Ph.D. candidates for potential careers in industry, particularly in high-demand areas like AI, robotics, and engineering. The soft skills needed to work in industry, such as design thinking, self-reflection and communication skills, and navigating the diverse perspectives of an interdisciplinary team, are also lacking in today's Ph.D. programs; this gap could be closed if students spent time in industry while attaining the degree. However, there is little incentive today for research faculty in very high research

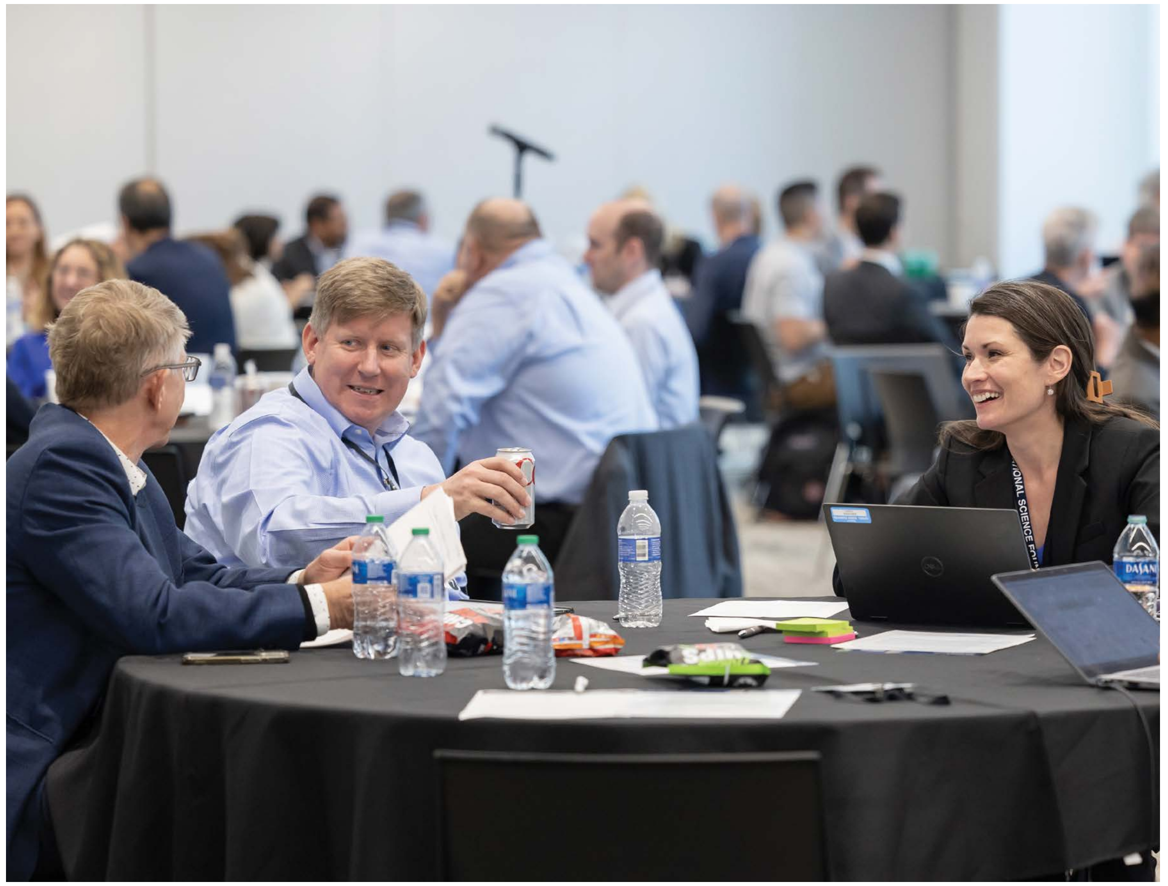


Credit: NSF

activity (R1 Carnegie Classification) universities to encourage promising graduate students to take advantage of these programs. Participants identified the need to shift the NSF grant-making incentive structure so that faculty voluntarily promote experiential learning opportunities.

In addition to more Ph.D.s in industry, upskilling through non-degree coursework, certifications, and practicum experience in industry could be leveraged to expand the talent pool. NSF's Experiential Learning for Emerging and Novel Technologies (ExLent) program, for example, begins to address this need by supporting experiential learning opportunities in emerging technology areas for individuals with diverse professional and educational backgrounds. To engage more diverse students, a cost-effective alternative could be achieved by industry co-investment with NSF in training programs at minority-serving institutions using shared course content. These programs could be aimed at those with an undergraduate degree or could be fashioned for current industry employees to augment technical knowledge in areas of highest need.

Participants noted that the current options to partner with NSF for workforce development are not well known. Creating a one-stop, online resource that offered all the options discussed—in-kind equipment sharing, mentorship, internships, faculty cost-sharing for training, etc.—would make it easier for industry to partner.



Credit: NSF

Taking the Pulse of the Room

NSF Assistant Director for TIP Erwin Gianchandani and TIP Division Director for Innovation Ecosystems Thyaga Nandagopal led a wrap-up discussion to identify top-line takeaways and outline next steps for NSF engagement with industry. They affirmed the TIP Directorate's commitment to continue the conversation and to extend it to a deeper level around key discussion points, such as IP and co-investment technology areas.

As new models take shape for industry to co-fund and collaborate on research with NSF, Gianchandani said the TIP Directorate is positioned to experiment with approaches for IP management that recognize industry needs. Further participation from industry representatives is essential, however, to co-create IP models that work for all parties, identify technology areas ripe for investment, evaluate and improve communication mechanisms, and create opportunities to accelerate translational research.

KEY FINDINGS

More industry participation in NSF efforts. One overarching need is to expand the number and size of companies that can co-invest with NSF in funding opportunities. Small to medium-sized companies and startups offer valuable use cases, facilities, and technical capabilities, but lack resources internally to support ongoing engagement, such as project managers and partnership officers. An NSF resource to assist with coaching and simplification of processes could make broader participation possible.

Solution-oriented IP approaches. Funded research can lead to new discoveries, and the IP emanating from research can create opportunities for potential development if the pathway to commercialization is transparent, rational, and not needlessly complex. NSF has developed approaches that work, but new models are needed for companies to partner at different investment levels, including new IP management approaches. Models are also needed that recognize tangible, non-monetary contributions such as facilities, use cases, and other in-kind assets as co-investment options. Selecting from a menu of approaches and options from the start would simplify decision making for companies that desire to collaborate.

Move faster. There is a need to reduce the timescale for NSF engagement (from idea to solicitation) and to reduce the paperwork burden so industry can more easily collaborate with NSF. One option is to consider co-funding pilot programs with the option to scale and increase investment at the three to six-month mark.

Better communication. Regular, industry-facing communication from NSF is needed to inform companies about opportunities to meaningfully engage in research activities. There is also a need for an NSF web presence specifically for industry partners (and potential collaborators).

Greater connectivity. Participants desire regularly established meetings that bring industry representatives together to share challenges and identify solutions, segmented by technology interest area. Meeting with NSF program managers that align with research interest areas could offer opportunities for industry representatives to help inform and shape future funding opportunities and build informed technology roadmaps.

Experiential learning. For workforce development, find ways to connect NSF-supported researchers and Ph.D. students with experiential opportunities in industry.

Research levels closer to industry interests. To make the transition to translational research, support projects at the technology readiness level of three or higher.

Onramps for new partners. Approaches that allow for additional companies to join projects after initial funding rounds would allow more companies to participate, perhaps at lower funding levels if offering in-kind value (use cases, test beds, etc.).

Soft-skill capabilities. Design thinking, communication, and multidisciplinary team dynamics are workforce needs that should be emphasized alongside technical skills in both academic and experiential learning.

Researcher awareness. Support engagement with academic researchers so they understand the value of use-inspired and translational research and how it relates to economic growth.

Tools development. A co-investment model involving industry and NSF could be leveraged to stand up tools that could be used across an industry sector, e.g., data standardization and platforms, digital twin capabilities, etc.

Multi-agency work. Engage in multi-agency (and multinational agency) funding for technology development in grand challenges to pool more resources and accelerate progress.

Appendix: Industry Representatives

Afia Afzal, Johnson & Johnson

Antonia Arnold-McFarland, Deere and Company

Robert Ashcraft, Samsung Semiconductor, Inc.

Gerard Baillely, Procter & Gamble Company

Bahar Biller, SAS

Alex Boakye, SAS

James Brokaw, ARA

Chris Brooks, Honda

Ashley Conboy, LAM Research

Gabriella Cruz-Thompson, Intel Corporation

Susana Diaz-Amaya, Bayer

Rick Dorval, Optics 1

Karina Edmonds, SAP

John Evans, World Wide Technology

Elena Fersman, Ericsson

Michael Foley, Deerfield Discovery and Development

Stephanie Frye, EMD Group

Gerald Furniss, Spirit AeroSystems

Sudhir Gowda, IBM

Joel Harris, Mars, Incorporated

Chris Hewitt, BASF

Tom Holcombe, BASF

Jody Howard, Caterpillar Inc.

Neena Imam, NVIDIA

Uma Jha, L3Harris Technologies

Charles Johnson-Bey, Booz Allen Hamilton

Guy Joly, 3M

James Kainz, ARA

Ramana Kompella, Cisco

Anna Lis Laursen, IBM

Gerrit Leusink, Tokyo Electron Limited

Jared Linck, SAS

David Luebke, NVIDIA

Phil Matthews, Boeing

Jim Medica, Dell

Richard Muisener, Evonik Corporation

Kailash Narayanan, Keysight Technologies

Prem Natarajan, Amazon

Karen Nelson, Thermo Fisher Scientific

Amanda Palumbo, Dow

David Parrillo, Dow

Stephen Pawlowski, Micron Technology, Inc.

Chandra Ramanathan, Danaher Corporation

David Rapaport, Siemens

Gregory Ratcliff, Vertiv

Dianne Ripberger, PepsiCo

David Shahoulian, Intel Corporation

Alexa Sharrar, Google

T. Sridhar, Juniper Networks

Robert Sues, ARA

Suresh Sundarababu, NI

Mallik Tatipamula, Ericsson

Phil Taylor, Bayer

Dustin Todd, Synopsys

Jan Vandenbrande, SRI International

Mark Veich, Deerfield Management

Evelyne Viegas, Microsoft Research

Andrew Walenstein, Blackberry

Brandon Wang, Synopsys

Jack Wells, NVIDIA

Sarah Windsor, Fujifilm Diosynth Biotechnologies

Rani Yadev-Ranjan, Ericsson

Wendi Yajnik, Novartis

References

[1] *"TRLs are a compendium of characteristics that describe increasing levels of technical maturity based on demonstrated (tested) capabilities. The performance of a technology is compared to levels of maturity (numbered 1-9) based on demonstrations of increasing fidelity and complexity." Government Accounting Office 2020. Technology Readiness Assessment Guide, https://www.gao.gov/products/gao-20-48g*

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