Aligning Interests in Support of Chemistry Research

A UIDP Academy Workshop
November 9-10, 2022

UIDP
Strengthening University-Industry Partnerships

Workshop Report

Organizer
Anthony Boccanfuso, UIDP

Co-Chairs
Peter Dorhout, Iowa State University
Lee Ellen Drechsler, Procter & Gamble

This material is based upon work supported by the National Science Foundation (NSF) under award #2236626. Report finalized March 20, 2023.

Any opinions, findings, interpretations, conclusions, or recommendations expressed in these materials are those of its authors and do not represent the views of the UIDP Board of Directors, UIDP's membership, or the National Science Foundation.

Contents

UIDP convened this workshop on behalf of the NSF Chemistry Directorate to identify areas of mutual interest in which companies can co-invest for use-inspired research.

Acknowledgments

UIDP would like to thank the National Science Foundation, and specifically the Division of Chemistry, for its financial investment in this workshop, as well as Iowa State University for its support, and the University of Arizona Washington, D.C. Center for Outreach and Collaboration, which served as our local host. The event co-chairs were Peter Dorhout, vice president of research at Iowa State University, and Lee Ellen Drechsler, senior vice president at Procter & Gamble, who, along with Pete Ellingson, open innovation manager at Procter & Gamble, were integral in providing programmatic guidance and identifying and securing a strategic set of academic and corporate participants. Stewart Witzeman, former director, Eastman Innovation Center, served as a consultant for this project and lead author for this report, with support from JoonHyung Cho, University of Virginia; Elizabeth Drotleff, The Ohio State University; Ralph House, University of North Carolina Chapel Hill; Sacha Patera, Princeton University; Caroline Trupp Gil, the American Chemical Society; and Naomi Webber, Lewis-Burke Associates LLC. Finally, UIDP is grateful to the 55 workshop participants representing 16 companies and 15 universities who dedicated their time and expertise to contribute to these discussions.

About UIDP

UIDP is a United States-based nonprofit membership organization comprised of leading innovation companies and research-intensive universities from around the globe. UIDP is dedicated to supporting mutually beneficial university-industry collaborations by developing and disseminating strategies to address common issues between the two sectors. Recognizing the vital role that government can play in supporting multi-sector partnerships, UIDP regularly partners with federal agencies in areas of mutual interest.

Executive Summary

Chemical companies have a significant track record of engaging higher education institutions through internships, facility access and use, co-location of research personnel, and industry-sponsored research projects. Concurrently, federal agencies, such as the National Science Foundation (NSF), have invested significant resources to explore ways to increase industry co-investments in areas of mutual interest. In recent years, NSF and other government agencies have partnered with companies to co-develop and co-fund calls for research proposals from academic researchers through joint solicitations (e.g., the Resilient & Intelligent NextG Systems [RINGS] program).

With support from NSF, UIDP convened a strategic set of academic, corporate, and nonprofit representatives for the workshop, "Aligning Interests in Support of Chemistry Research," held Nov. 9-10, 2022, in Washington, DC. The participants included representatives from academia with experience conducting industry-funded research as well as industry representatives with programmatic responsibilities for sponsored research and the ability to take part in a co-investment program with a government agency.

Workshop Goal: To identify precompetitive areas of mutual interest in which companies can co-invest with government agencies for use-inspired research conducted in academic and nonprofit settings.

Both corporate and government participants expressed a willingness to work together for mutually beneficial outcomes. The importance of focusing on use-inspired, precompetitive research[1] was emphasized in particular. Co-investment by companies and government agencies in government-issued solicitations was of high interest to workshop participants (see Appendix B for the participant list and Appendix D for survey results).

During the workshop, participants explored the joint solicitation process currently in use in the United States and approaches used in other countries. Participants identified two potential (and significant) barriers—differing timelines and the handling of intellectual property (IP)—as the most prominent challenges to corporate-government collaboration. The government timeline was established at 10 months from when a joint solicitation is released for researcher response and when that research project starts, and the internal government approval process adds additional time. Industry seeks a more streamlined process and proposed an 11-month timeline from the initial discussions with co-funders until the start of research projects, including internal approvals. Although the government solicitation process typically does not include substantive industry input, multiple opportunities for industry input were identified—determining focus areas, writing the solicitation, participating in proposal review, and collaborating with selected teams.

> Industry seeks a more streamlined process and proposed an 11-month timeline from the initial discussions with co-funders until the start of research projects, including internal approvals.

> Developing nimble and reproducible approaches to industry-government partnerships is critical to greatly enhancing the number of jointly created opportunities for academic researchers.

Previous jointly-funded solicitations provide insights on how best to manage foreground IP resulting from the academic research these programs support. Participants agreed that a detailed discussion of IP is premature. Specifics of IP terms should be determined after the research focus area is formulated. From discussions of the Horizon Europe and A*STAR program models, participants said that consistent industry involvement in research topic development and resulting partnerships was the primary benefit derived. Active industry engagement helps focus research efforts on areas with key technical and economic benefits.

Four potential focus areas emerged from large group and breakout discussions for mutual investments:

- Enabling Platforms for Polymer Characterization
- Decarbonization through Recycling and Upcycling
- Recycling Education
- Cross-functional Skills between Chemists and Data Scientists

> "This NSF workshop was an exciting first step in accelerating the broad-scale adoption of sustainable chemistry innovation across the U.S. Bringing academic and industrial thought leaders together on specifically chosen themes early would enable the best ideas to come to life with maximum impact. We look forward to partnering more closely on top-quality NSF-sponsored research being done across U.S. universities."
>
> *— Lee Ellen Drechsler, senior vice president at Procter & Gamble, workshop co-chair*

Enabling Platforms for Polymer Characterization

Establishment of a "trusted" suite of academic-based digital and experimental labs that can build scientifically trustworthy and actionable precompetitive research assets for polymers for either soft matter or advanced material applications is an attractive area for further exploration. Specifically, participants recommended creating a jointly funded program that supports a network of labs and interdisciplinary teams to develop findable, interoperable, accessible, reusable data on characteristics of polymers, ranging from structure to biodegradation. The research assets to be developed include high throughput synthesis experimental, characterization, metadata, machine learning techniques, and simulation. Ultimately, any investment will enable predictive structure-to-property modeling for sustainable technologies. Development of these research assets will be game-changing for discovery and in-market use of breakthrough polymers and materials.

Decarbonization through Recycling and Upcycling

Workshop participants were interested in development of new products that repurpose material from existing waste streams (upcycling) and redesigning existing products (including physical redesigns and the development of new modifiers and additives) to allow products to be returned to their base material state (recycling) in a less energy-intensive and wasteful way. The first research thrust is to create new materials from existing feedstocks without attempting to return material to its original form. The second thrust is to redesign elements of products and packaging that prevent these materials from being recycled. Recycling such materials includes additives introduced at the end of the process.

Cross-functional Skills between Chemists and Data Scientists

A common theme during the workshop was the need for chemists to become proficient in data science and for data scientists to have a baseline knowledge of chemistry. Participants expressed interest in developing pathways to foster connections between chemistry and data science through cross-training of current undergraduates, graduate students, postdocs, and professionals. In addition to cross-training, workshop participants would also like to see team development that encourages greater knowledge exchange between chemists and data scientists. The development of a seven-week online course that could be integrated into current university degree programs was proposed as a first step.

Recycling Education

Recycling education was outside the intended research scope of the workshop, but participants pointed to its critical role in sustainable chemistry. Even if new materials or existing materials can be recycled in an energy-sensitive way, robust community recycling programs are needed. Workshop participants proposed the development of new, innovative programs and advancing community education and access to recycling programs to increase the amount of recyclable material that is actually recycled, building upon programs like the National Institute of Standards and Technology circular economy training grants.[2] Details of the recycling education discussion can be found in the full workshop report.

Focus areas, goals, and next steps from the breakout discussions are summarized below.

Enabling Platforms for Polymer Characterization

Goal

Establish a 'trusted' suite of digital and experimental labs that can build scientifically trustworthy and actionable precompetitive research assets (high throughput synthesis experimental, characterization, metadata, ML techniques, simulation) for polymers for either soft matter or advanced material applications. These labs and their research assets will ultimately enable predictive structure-to-property modeling for sustainable technologies. This will be game-changing for discovery and in-market use of breakthrough polymers and materials.

Next Steps

- Identify the appropriate consortium model, associated funding streams, required finding level, and IP approach.
- Identify consortium members – polymer consumers (chemical companies) and analytical chemistry labs (academic labs and national labs) – and agree on the consortium's membership criteria, benefits, and outcomes.

Decarbonization through Recycling and Upcycling

Goal

Reduce carbon emissions by optimizing product life cycle through (1) developing new products that repurpose material from existing waste streams (upcycling) and (2) redesigning existing products (including the physical redesigns and the development of new modifiers and additives) to allow products to be returned to their base material state (recycling) in a less energy-intensive and wasteful way.

Next Steps

- Determine which companies are interested in funding a joint solicitation on this topic and the level of funding they prefer.
- Refine the scope of the topic to fit within the funding level that the companies desire.

Recycling Education

Goal
Increase the amount of recyclable material that is actually recycled by developing new, innovative programs and advancing education and access to recycling programs.

Next Steps
- **Testbeds:** Fund the design and implementation of new, innovative approaches to recycling education and implementation to increase the percentage of currently recycled material being recycled. Universities are one example of a uniquely interwoven community in which many processes and procedures can be designed in a reasonably centralized way. As such, a university (or similar type of close-knit community) can serve as a testbed for new recycling programs and educational approaches. Additionally, universities are the home to bright academic minds who can evaluate relevant aspects of psychology, availability of information, and physical infrastructure to enable meaningful ways to increase recycling.
- **Education programs:** There is a need for baseline education and broader availability of recycling programs. Many under-resourced communities do not have access to recycling programs and are not knowledgeable about materials that can or cannot be recycled. Increasing the availability of recycling programs and community education about what and how to recycle can vastly increase the amount of material recycled.

End-of-life Optimization and Workforce Needs

Goal
Develop pathways to foster connections between chemistry and data science by cross-training current undergraduates, graduate students, postdocs, and professionals and building teams that encourage greater knowledge exchange between chemists and data scientists.

Next Steps
- Develop a 7-week course for chemists on the basics of data science.
- Make the course available online to be leveraged by existing chemistry programs.

Aligning Interests in Support of Chemistry Research

Purpose of this Workshop

The impact of the chemical sciences on the U.S. economy is significant, with an estimated $5.2 trillion annual contribution to the U.S. GDP from direct and indirect activities.[3] Representative applications span the pharma, agricultural, chemical, consumer products/personal care, and energy sectors, among others. These industries have a long history of innovation driven by market and societal needs. The pace of these innovations is greatly accelerated by well-documented macro trends, such as the need for more sustainable, less carbon-intensive products and increased demand for products and processes with a better environmental or toxicological footprint. These activities are further driven by an increasingly aware consumer base that expects solutions to these issues.

To address challenges and accelerate use-inspired research, federal agencies have adopted joint funding approaches that engage industry early in the process and combine government funding with up-front investment from companies that have an interest in research outcomes. Joint funding solicitations have been used by the Technology, Innovation and Partnership (TIP) Directorate and various units within the National Science Foundation (NSF), including the Computer and Information Science and Engineering (CISE) directorate. Examples include the NSF/VMware Partnership on the Next Generation of Sustainable Digital Infrastructure (NGSDI),[4] many of the National Artificial Intelligence (AI) Research Institutes,[5] and Resilient & Intelligent NextG Systems (RINGS).[6]

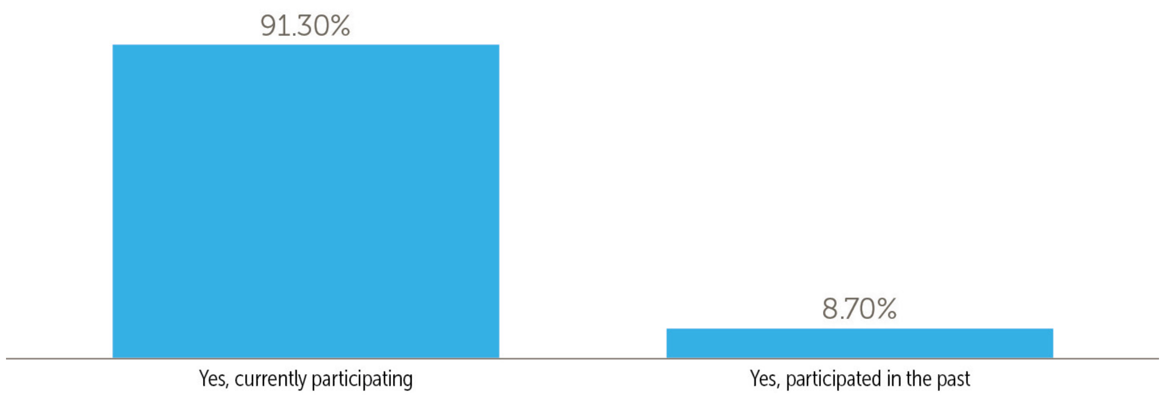
To catalyze corporate and government partnerships in new research areas of mutual interest, UIDP organized a Nov. 9-10, 2022, NSF-sponsored workshop, "Aligning Interests in Support of Chemistry Research." **The specific charge of the workshop was to identify precompetitive areas of mutual interest in which companies can co-invest with government agencies for use-inspired research conducted in academic and nonprofit settings.**

Background and Previous Studies

A number of studies convey the impact of the chemical sciences on the U.S. economy, while others identify key issues associated with improving collaboration between industry and academia. One example is a recent study by the National Academies of Science, which identified the importance of collaborative research and the potential role government agencies can play in supporting this research.[7]

In advance of the workshop, UIDP surveyed industry representatives from companies highly engaged in sponsored research with universities; more than 90% are currently funding university research (see complete results in Appendix D). Additionally, 95% of respondents said they are highly interested in collaborative research with other companies, and 85% indicated interest in partnering with government agencies to co-invest in academic research.

Industry Participation with Academia in Government-sponsored Research



The most significant barriers to partnership were identified as intellectual property (IP) issues, the relevance of funding opportunities to areas of industrial interest, and differences in timelines between industry and government-funded efforts. The relative importance of these issues varied between the overall respondent pool versus the workshop participants and is discussed further in Appendix D.

This pre-workshop survey helped prioritize issues discussed and topics for breakout sessions during the event. The results were consistent with previous UIDP member surveys where issues impacting such engagements included:

Time requirements: Solicitation response time and the need for more time to allow meaningful engagement between prospective partners to develop proposals;

Due diligence: Better due diligence by universities to identify prospective corporate partners;

Transparency: Increased transparency and understanding of the U.S. government solicitation process by industry; and

Needs identification: A better process for sharing both federal priorities and industry needs.

Workshop Session Highlights from Day 1

Workshop Charge

Discussants: Lee Ellen Drechsler (Procter & Gamble); David Berkowitz (NSF); and Peter Dorhout (Iowa State University)

Discussants introduced the workshop charge, to identify precompetitive areas of mutual interest in which companies can co-invest with government agencies for use-inspired research conducted in academic and nonprofit settings.

To set the stage for the day's discussions, Peter Dorhout highlighted the contrast in university and industry perspectives on the innovation ecosystem since both sectors operate under varying reward systems. Programs to foster collaboration between companies and universities must provide the benefits that investing companies seek while respecting the needs of university faculty and students. For example, industry sponsored research conducted by faculty members should count toward the tenure and promotion process. Additionally, graduate students need the ability to publish their work so it counts toward their dissertation or thesis.

Similarly, Lee Ellen Drechsler put forward industry's objective to enable use-inspired, scalable research through public and private funding schemes and to identify pragmatic co-creation approaches to drive partnerships between companies, universities, and government agencies.

Companies and governments are making substantial investments in areas of societal need. This workshop focused specifically on the chemical sciences and on sustainability, where the opportunity for co-investment could lead to greater impact by multiplying the dollars invested in strategic and societal research needs and could de-risk research investments in new technologies to benefit society.

Key Opportunities and Challenges

- **Contrasting needs.** Designing a program that will meet the needs of companies, universities, and society more broadly.
- **Misaligned timelines.** Coordinating the contrasting timelines utilized by industry and government.
- **IP issues.** Selecting an IP approach that will comply with government funding regulations, benefit industry investors, and be palatable to university researchers.
- **Appropriate research directions.** Selecting research focus areas that are truly precompetitive.

Primary Benefits

- **Ability to leverage capabilities.** Neither industry nor academia can cost-effectively address complex R&D challenges alone. Collaboration will help de-risk research needed to address big challenges.
- **Potential to see fundamental research translated to broader applications.** By providing industry input into the solicitation framing, the likelihood of the research results applying to future commercial and societal advances is significantly higher. Additionally, industry involvement can impact and improve U.S. competitiveness through increased commercialization.
- **Broad reach.** By working with a trusted partner such as NSF, academic researchers are more likely to become aware of and pursue opportunities.

Non-U.S. Models

Panelists: Rick Muisener, Evonik; and Scott Fagan, PepsiCo R&D; Stewart Witzeman, UIDP (facilitator)

Other countries have developed and used collaboration models that combine multiple funding channels to drive research-based solutions to technical challenges. Leveraging what works in other countries can increase U.S. competitiveness and benefit industries that use chemistry to develop products and services. Notable examples include:

- UKRI Industrial Case Studentship. Graduate student training programs in industry, financially supported by the UK government, to prepare students for careers outside of academia. Ph.D.-level students spend an extended period of time in an industry lab as a part of their academic program.
- Horizon Europe. This program includes industry in early-stage discussions and uses funding models that recognize the need for interdisciplinary research that engages multiple stakeholders. Horizon Europe brings together participants from both academia and industry to develop and ultimately commercialize the technology. Industry participants span sectors and the value chain, which helps with technology development and (ultimately) commercialization.
- Singapore's A*STAR Model. The A*STAR (Agency for Science Technology and Research) Model involves government investment in research infrastructure that fosters development in areas of economic interest. Singapore's RIE2025 Plan involves $25 billion in R&D investment to sustain competitiveness and build innovation. This model includes clear descriptions of IP disposition, which speeds the contracting process and creates efficiencies.

In general, these models start with programs aimed at advancing technology at low technology readiness levels (TRLs) and then provide mechanisms for follow-on work at higher levels.

Program success elements include being clear about roles and expectations and aligning programs with areas of high corporate priority. Industry benefits include IP, access to unique capabilities without a need to hire, avoided capital and other costs, and access to talent and new employees.

U.S. government agencies should evaluate these programs and adopt successful practices from other regions, such as openness to new models and ways to include multiple parties in programs.

Models for Current Joint Funding Solicitations

Speaker: Graciela Narcho (NSF)

NSF's Technology, Innovation and Partnerships Directorate (TIP) aims to help the nation address global competition, including diversity in STEM education, while addressing socioeconomic challenges (changing climate, equitable access to education and health care, critical and resilient infrastructure) through evolution of the research and innovation ecosystem.

Technology, Innovation and Partnerships is a new NSF directorate that creates breakthrough technologies; meets societal and economic needs; leads to new, high-wage jobs; and empowers all Americans to participate in the U.S. research and innovation enterprise. TIP is a unique opportunity that engages the nation's diverse talent in strengthening and scaling the use-inspired and translational research that will drive tomorrow's technologies and solutions.

This directorate represents a paradigm shift from academia-driven ideas (push) to a market demand model (pull). TIP is not designed to change the NSF mission, but rather to accelerate and scale basic research. It was described as a new "horizontal" to enhance use-inspired and translational research. (See NSF Partnering Principles and Partnership Landscape Study.)

TIP is intentionally different from other NSF directorates in terms of large-scale efforts, the use of co-design and co-creation with industry, and IP ownership models.

Traditionally, when companies invest in NSF-funded projects, the solicitation for research proposals is written exclusively by NSF, academic researchers apply for the funding (and identify potential industry partners as a part of the application process), and then companies provide matching dollars or in-kind contributions if their academic partner is awarded.

The Joint Solicitations Model

While TIP still uses traditional funding mechanisms, newer models have emerged. In particular, a number of joint solicitations have been released by the TIP and Computer and Information Science and Engineering (CISE) directorates. This approach involves industry much earlier in the process, and companies work directly with NSF to determine an area of mutual interest, craft the solicitation, and make a financial commitment up front. NSF has final selection authority, and the company funds the university that is awarded by NSF (regardless of whether that university had a preexisting relationship with the company). This is one model; in another, the funding is transferred. Examples of joint solicitations include the NSF/VMware Partnership on the Next Generation of Sustainable Digital Infrastructure (NGSDI), many of the National Artificial Intelligence (AI) Research Institutes, and the RINGS program. To date, most joint solicitations have resided in the information technology or computer science space; this workshop is the first to focus on potential joint funding opportunities in the chemical sciences.

In the current joint solicitations model, an industry partner and NSF must develop a memorandum of understanding (MOU) that includes the following:

- **Resource commitment.** This includes both level of funding required and length of commitment.
- **Role in funding opportunity development.** Companies often provide substantive input into the direction of the jointly funded solicitation, and NSF approves the final language.
- **Role in merit review process.** NSF's broad reach and the objective nature of its merit review process are often cited as motives for companies to partner with NSF on a solicitation. The merit review process is not substantively modified when companies co-fund a solicitation. However, companies can play a role in providing input into the selection process. The details of how this input is generated and received are captured in the MOU.
- **Role in award selection.** NSF retains the authority to make the final proposal selection decisions. Companies can choose to participate in the process but should be aware that it is a substantive time commitment.
- **Process of funds transfer.** This includes how funds are transferred, timeline for transfer, and cost split between NSF and industry. In cases where a group of companies co-fund a solicitation, funds are usually transferred to NSF, which then transfers funds to awardees. In cases where a single company is co-funding the grant, the company may choose to transfer funds directly to awardees.
- **IP rights.** Foreground IP (FIP) rights are outlined in the MOU. NSF does not manage background (or pre-existing) IP. To date, the FIP for most joint solicitations is covered in either an open source, public access, or non-exclusive, royalty-free license (NERF) approach, but other arrangements are possible.
- **Post-award engagement.** The extent to which companies intend to engage with awardees during the course of their research should be determined during the development of the MOU.

As of November 2022, approximately 10 MOUs have been developed for various sources of industry funding. The time to establish an MOU for a new industrial partner is six to seven months, but the advantage of working with NSF is its broad reach to the academic research community.

Overview of the NSF Funding Call Development Process

Speaker: Lin He, Deputy Division Director, Chemistry Division, NSF

Funding calls are developed with information and input from several sources. Some use "bottom-up" input from the research community gathered through mechanisms such as workshops, NSF-issued requests for information (RFIs), and NSF-sponsored advisory committees. Other solicitations are developed by NSF program directors from "top-down priorities" identified by the administration and agencies; these are developed with community input to address the research needs and advance science and technology frontiers. NSF encourages all stakeholders to participate in the information-gathering process and is eager for increased engagement from industry to identify knowledge gaps and areas of interest to advance fundamental research and technology development. These strategies inform NSF about topics to consider for a solicitation.

Developing the Call

Once a topic has been identified, NSF leadership evaluates and approves the scope and mechanism. Internal and external entities (other government agencies, companies, nonprofits, and international agencies) are considered as potential partners for the draft call. After input from relevant parties, the call is updated and approved internally; the new funding opportunity is announced through either a "Dear Colleague" letter or a formal solicitation. A solicitation provides further details about proposal requirements, review criteria, and other elements for submission. NSF uses targeted dissemination channels and other vehicles, such as webinars and outreach opportunities for program leadership to disseminate funding calls and answer questions from interested principal investigators (PIs).

Funding call examples:

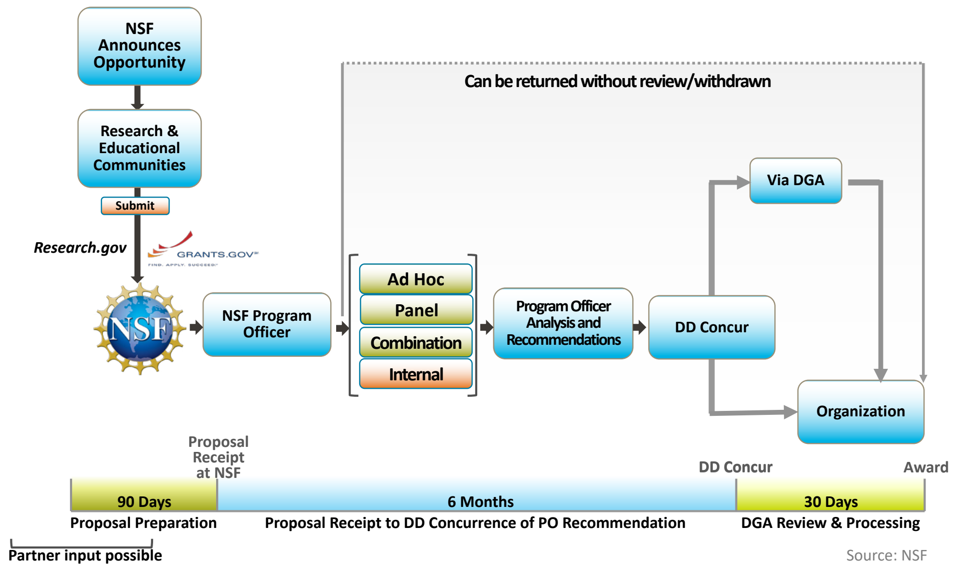
- **Center/institute research proposals:** Approximately $3 million annually for five to 10 years. These generally involve six to 12 PIs and 15 to 30 students.
- **Faculty research proposals:** Beginning at $200,000 per year for two to four years with one to three PIs and two to four students.

- **Student training and education proposals.** For these proposals, award size varies based on the funding mechanism.
- **Other proposal types:** For facilities, equipment, conference/workshop, travel, etc.

NSF Proposal Review Process

NSF requires a minimum of 90 days from the time of the new funding call announcement for a PI to respond. Proposals are evaluated on intellectual merit and broader impacts as defined by the National Science Board (NSB), in addition to other solicitation review criteria.

Life of an NSF Proposal



Source: NSF

NSF-catalyzed academic-industry partnerships include:

- GOALI, **Grant Opportunities for Academic Liaison with Industry.** The university partners with one or more companies to submit a solicited or unsolicited research proposal. GOALI's success is dependent on a PI's cultivation of industry partners.
- IUCRC, **Industry-University Cooperative Research Centers.** NSF provides funding to allow the university organizers to coordinate a topic-specific consortium. Industry members support the consortium via membership fees and have a say in how the research funding is invested.
- INTERN, **Internships for graduate students.** NSF funding enables graduate students to spend time at a company or in any non-academic lab setting.

Another model of NSF-industry direct partnership is through a non-IUCRC consortium model, in which NSF works directly with an industrial consortium to co-fund research. The RINGS program is an example of a consortium formed for a solicitation co-funded by industry and NSF.

This model has never been used for a chemistry-related program and is the approach participants in this workshop considered. In this model, the process for developing a call may

take six months when only one company is involved or longer as more companies join the effort, in part because of the lengthy negotiation process and challenges in aligning financial calendars. During workshop discussion, participants from industry expressed a desire to reduce the length of time and sought ways to make the process more efficient.

For joint solicitations, the extent to which companies comment on the proposals they would like to see funded can be negotiated, but NSF makes final funding decisions. The extent to which companies work with the funded academics can also be negotiated; if there is a desire for robust collaboration between company representatives and academic researchers, the management of those collaborations is factored into the overall budget.

RESILIENT & INTELLIGENT NEXTG SYSTEMS (RINGS)

RINGS funds research in two broad groups of NextG technologies and a number of subthemes within each group. RINGS is a joint solicitation involving NSF, the Office of the Under Secretary of Defense for Research and Engineering (OUSD R&E), the National Institute of Standards and Technology (NIST), and nine companies. Awardees receive funds in the form of an NSF grant (with associated NSF stipulations). The participating companies equally fund the program, and the contents of the solicitation are jointly developed with all funding entities (government and companies). To align interests and streamline the process, the companies formed an industry working group. The solicitation was executed through NSF's established process.

For joint solicitations, the extent to which companies comment on the proposals they would like to see funded can be negotiated, but NSF makes final funding decisions. The extent to which companies work with the funded academics can also be negotiated; if there is a desire for robust collaboration between company representatives and academic researchers, the management of those collaborations is factored into the overall budget. All funding entities receive Non-Exclusive Royalty Free agreements (NERFs).

Pulse of the Participants

Discussion leaders: Amanda Palumbo, Dow Chemical Company; Travis Williams, University of Southern California

At the end of the first workshop day, discussion leaders summarized five key takeaways from the proceedings:

- **More efficient (faster) processes** are needed to enable more NSF-direct partnerships with industry.
- **Engaging industry early** in the process is beneficial and increases the likelihood of success.
- Applicable learnings may be derived from **benchmarking processes and learnings from similar programs** across the globe.
- In addition to topic-specific research, industry desires **talent development and a diverse pool** from which to draw the next generation of STEM leaders from its academic engagement efforts.
- **Balancing the need to protect national interests with the desire for global collaboration** is a key challenge.

Workshop Session Highlights from Day 2

Technical Areas Ripe for Joint Funding Approaches

On the second workshop day, participants sought to identify potential precompetitive topics of interest to academic researchers that could be co-funded by industry and government. The discussion was informed by a pre-workshop survey fielded by the organizers. Many of the potential topics emerging from the survey pointed to sustainability goals shared by academia, industry, and governments. Eight topics were identified and refined:[8]

- Low/zero/negative carbon intensity raw materials
- Recyclability and degradation
- Virgin plastics alternatives
- Enabling technologies
- Macrotrends/changes due to climate and the need to accelerate knowledge transfer to achieve a sustainable future
- Dual-domain skills (STEM + digital)
- Accelerating knowledge transfer to achieve a sustainable future
- Other areas

Based on Day 1 learnings, participants considered the major research domains that can benefit from joint investment from chemistry-focused companies and government agencies with an interest in use-inspired, precompetitive research. Four topics emerged and were developed during in-depth breakout sessions:

- Enabling Platforms
- Decarbonization
- Recycling and Upcycling
- End-of-life Optimization and Workforce Needs

All four breakout groups were charged with identifying chemistry-focused, precompetitive research needs that will benefit society and advance sustainability goals. Each breakout group comprised industry and university representatives with experience managing research partnerships and research portfolios. One or more academic researchers were included in each to provide technical insights into feasibility, current research trends, and the likelihood that a solicitation will be received well by the academic research community. The industry representatives were also asked to consider the level of need for the research from both a societal impact and an industrial perspective, and the likelihood that a research direction will be funded by their respective companies.

A cross-cutting theme, the need to incorporate workforce development needs, was discussed in each breakout group as an underpinning element.

Breakout Session Highlights

Enabling Platforms for Polymer Characterization

Facilitator: Gerard Baillely, Procter & Gamble

Research Focus: Establish a "trusted" suite of digital and experimental labs that can build scientifically trustworthy and actionable precompetitive research assets (high throughput synthesis experimental, characterization, metadata, ML techniques, simulation) for polymers for either soft matter or advanced material applications.

Societal Impact: This proposed network of labs and associated research assets will ultimately enable predictive structure-to-property modeling for sustainable technologies. This will be game-changing for discovery and in-market use of breakthrough polymers and materials.

Predictive modeling to enable high throughput polymer screening is a current research gap; to date, most polymer R&D has been devoted to specialty polymers and macromolecules. The development of enabling platforms that integrate machine learning and experimental approaches to characterize the functionalities of new and existing soft material polymers and solid-state materials will open a channel for faster innovation.

Rather than focusing on a specific type of material for a jointly funded solicitation, the breakout group discussion moved rapidly to establishing a lab-to-scale discovery factory to support pre-competitive research on high throughput macro and micro polymer synthesis, techno-economic analysis, and sustainability implications of both soft matter polymers and solid-state materials. The proposed discovery factory will create a network of government and university-based labs to serve as an agile, distributed network. Within this network, value is increased by developing standardized systems to measure and accurately characterize the material for future competitive research. Data developed and verified through enabling platforms should follow the FAIR (findable, accessible, interoperable, reusable) standards and account for ethical considerations.

Researchers would seek to understand the properties and functionalities of the material and derive standard metrics and parameters to accurately describe capabilities. Although analysis of polymers takes place on an ad hoc basis now, the goal of this initiative will be to develop a trusted data resource where information can be compared across polymers and where the conclusions are validated, reproducible, and accessible to other researchers. The platforms' output can serve as a trusted information resource for industry and academics to advance further research.

The participants stipulated that multidisciplinary teams from both industry and academia—including expertise in chemistry, data science, chemical engineering, microbiology, and standards development—will accelerate the transition from lab to industry applications. When crafting the solicitation, industry should be included in specifying the types of outcomes data and standards needed for end use; this is more critical than putting close parameters on which polymers to study.

To broaden impact, the project can develop a curriculum for smaller institutions and community colleges and provide a training ground for technical workforce development at all levels—technicians and operators as well as Ph.D. students and postdocs. To accelerate discovery, the enabling platforms will combine elements of automation by leveraging computational and data analytic expertise, using machine learning to systematically develop discovery pathways.

Decarbonization

Facilitator: Scott Collick, DuPont

Research Focus: Identify the top 20 high-value chemicals and design new approaches to their synthesis and usage to allow for industrial adoption of lower carbon intensity approaches within five to 10 years.

Societal Impact: By coupling industrial expertise around existing manufacturing processes and infrastructure with the academic research community's expertise in chemical synthesis and carbon emission analysis, the carbon intensity of chemicals that serve as a building block for countless modern-day products can be reduced.

This breakout group evaluated logical pathways toward reducing carbon emissions in the short run. Participants set a goal of designing a program that will have impact within five to 10 years, canvas the entire value chain, and encompass both existing and new materials.

The group suggested that the top 20 high-value chemicals be identified by the industrial partners involved in the program. These will be carbon-intensive chemicals that are either used in multiple processes or used in large quantities in fewer processes. Future research options include

- modifying the current production process to reduce the carbon footprint of one of the selected chemicals, and
- developing chemicals that have lower carbon intensity than existing chemicals but can be substituted in current applications.

Ideally, any solutions developed will use 80% to 90% of existing infrastructure. Modifying manufacturing plants is expensive and takes a very long time to implement. Depending on the industry, workshop participants postulated that a manufacturing plant's lifespan ranged from 25 to 75 years. Therefore, large-scale modification of existing plants is not feasible in the short run.

Recycling and Upcycling

Facilitator: Amanda Palumbo, Dow

Research Focus: Investigate existing products and production pathways to (1) determine how current waste streams can be repurposed into new products, (2) evaluate how current processes can be modified, and (3) identify new base materials, additives, and design approaches to increase recyclability and decrease carbon intensity.

Societal Impact: To increase the recyclability of existing products and to lower the carbon intensity of both existing products and newly developed ones.

There are many reasons why current products are not recycled:

- The base material is not recyclable.
- The base material is recyclable, but additives or product design inhibit the recycling process.
- The product is not successfully transferred from the consumer into the recycling process.
- The recycled materials that can be made are too low in value.

This breakout group sought to identify future investments that can address one or more of the challenges posed above.

Repurposing waste streams and hard-to-recycle materials. Because a large proportion of recyclable material ends up in a waste stream and many products made from recyclable base material are not recyclable, the group proposed that researchers evaluate how materials found in current waste streams can be harvested to develop new products. It is possible that some products in a given waste stream may undergo chemical modifications that would allow the waste to be repurposed more easily than the original product. While this approach may not be sustainable in the long run, repurposing waste streams could help address the first two challenges the group identified.

Decreasing carbon intensity. The carbon intensity of the production of a base material is a notable factor in how sustainable the end product can be. The group recommended that researchers consider how high carbon intensity base materials could be modified or improved to allow new, lower carbon intensity products to come to market. This research idea had substantive overlap with the discussion from the decarbonization breakout group.

Current base material pathways to production. Specific processes within overall production can be optimized or redesigned to produce existing base materials with a lower carbon footprint. This research concept will require close collaboration between companies and academia to ensure that researchers have sufficient information on existing processes and opportunities for optimization. These may include discovery of a new pathway for chemical synthesis, modification of non-recyclable additives put on recyclable base materials, or removal of design elements that inhibit the recycling process. This research idea also had substantive overlap with the discussion from the decarbonization breakout group. Developing new routes to achieving existing products was identified as the most lucrative research topic.

New base materials development. The current market includes many carbon-intensive and non-recyclable base materials. As noted in the decarbonization breakout, there is a long lead time for developing material for use in new products. However, new materials development is a core requirement for moving toward carbon neutrality and increased recyclability.

In addition to modifying existing products and processes, the group suggested that researchers be inspired to **develop new products that may not be a one-to-one replacement for existing products**. Because this concept does not fall firmly in the precompetitive research space, it is not likely to be considered for a solicitation jointly funded by companies and government agencies.

RECYCLING EDUCATION

One challenge this breakout group sought to address was the issue of recyclable material not being recycled. This multifaceted problem includes gaps in community education, access to recycling programs, and consumer willingness to participate in existing programs. In this context, the group proposed two approaches. These approaches were not recommended for co-investment from companies and government agencies (the focus of the workshop). Instead, participants suggested that these ideas be presented to government and non-profit groups already active in recycling and community engagement efforts.

GOAL: INCREASE THE AMOUNT OF RECYCLABLE MATERIAL ACTUALLY RECYCLED BY DEVELOPING NEW, INNOVATIVE PROGRAMS AND ADVANCING EDUCATION AND ACCESS TO RECYCLING PROGRAMS.

TESTBEDS: Fund design and implementation of new, innovative approaches to recycling education and implementation to increase the percentage of currently recycled material. Universities are one example of a uniquely interwoven community in which many processes and procedures can be designed in a reasonably centralized way. A university (or similar type of close-knit community) can serve as a testbed for new recycling programs and educational approaches. Additionally, universities are the home to bright academic minds that can evaluate relevant aspects of psychology, availability of information, and physical infrastructure to determine meaningful ways to increase recycling.

EDUCATION PROGRAMS: There is a need for baseline consumer education about recycling and broader availability of recycling programs. Many under-resourced communities do not have access to recycling programs and are not knowledgeable about materials that can or cannot be recycled. Increasing the availability of recycling programs and community education about what and how to recycle can vastly increase the amount of material recycled.

End-of-life Optimization and Workforce Needs

Facilitators: Lee Ellen Drechsler, Procter & Gamble, and Peter Dorhout, Iowa State University

Research Focus: End-of-life optimization needs a systems approach. Students may be attracted by this concept, but they need expertise in data science and chemistry to pursue it. An adequately trained workforce can address any topic related to end-of-life optimization once these skills are acquired.

Societal Impact: Degradation (or lack thereof) of products after they are discarded has a major impact on the environment. Therefore, an important aspect of sustainability is optimizing products to degrade in favorable ways. Developing mechanisms to encourage degradation pathways with benign outputs is also important. By creating a workforce with dual capabilities in data science and chemistry, the end-of-product life can be optimized for ideal outcomes.

Although this breakout group's discussion began with the fruitful research directions associated with materials degradation, it quickly pivoted to the skills needed to advance the chemical industry's sustainability goals and potential approaches for meeting those needs. **Equipping the chemical industry workforce with the required skills to advance the industry was a recurring theme throughout the workshop.**

Initially, the group considered different end products and the need for those products to ultimately break down into benign materials. Participants quickly concluded that the area of greatest need relating to degradation relies on the availability of information and the ability to draw conclusions from this information. **The pathway to optimize product degradation is to combine tools from data science, artificial intelligence (AI), and machine learning with the expertise of chemists.**

The group highlighted both the need for chemists who are proficient in data science and for data scientists with exposure to chemistry and an interest in applying their talents to chemistry-driven applications. They expressed a desire to cultivate a future workforce with an understanding of both fields and to enable today's workers to function in a cross-disciplinary environment to leverage each other's skills.

The group proposed several solutions.

Ph.D.-level experiences in industry have been effectively leveraged in the UK and other countries and can advance chemistry workforce development in the United States. NSF (or other federal agencies such as the National Institutes of Health [NIH]) can play a role in financially supporting Ph.D. students working in industry as a means to foster cross-disciplinary skill development and industrial relevance within this training. For such a program, the research focus areas should be carefully selected to ensure the program effectively promotes cross-pollination of skills and experiences between chemistry and data science.

Chemistry curriculum development was another proposed solution. Chemists need a minimum baseline knowledge of modern data analysis to move the chemistry field forward at a rapid pace. In addition to groups such as the American Chemical Society (ACS) working to integrate data science, machine learning, and AI into the standard chemistry curriculum, the development of an additional short course that complements the ACS requirements was suggested. The group discussed development of a seven-week online module that any university could leverage to provide a baseline understanding of data science to current chemistry students.

Workforce needs. Related to training is the acknowledgment of related talent pipeline challenges in academia. Training students in AI and machine learning requires qualified faculty. Because these are lucrative fields in industry, it can be difficult for universities to recruit and retain AI and machine learning experts to join faculty in a traditional setting. An industry-developed online training module could close this gap for institutions that lack in-house capabilities.

The UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN has designed an innovative degree option, CS + X, that incorporates a strong grounding in computer science with other disciplines. **CS + Chemistry** majors might develop computer models or simulate chemical and biochemical processes, perform statistical analysis of large data sets, or create visualizations of reaction pathways, molecular interactions, or other phenomena. The University also runs a graduate program, Illinois Computing Accelerator for Non-Specialists (iCAN), that provides non-specialists a deeper understanding of computers, algorithms, and programming. The university is also home to an NSF/CHE AI Institute, the Molecule Maker Lab Institute, which aims to accelerate automated chemical synthesis "to advance the discovery and manufacture of novel materials and bioactive compounds."

Next Steps

During the subsequent large group discussion, participants identified similarities between the work proposed by the Recycling and Upcycling group and the Decarbonization group. A path forward proposed by the Decarbonization group was folded into the objectives outlined by the Recycling and Upcycling group.

> "I enjoyed convening to discuss and debate how to push the boundaries of collaboration further between industry, academia, and NSF. We have huge societal issues around sustainability, and we'll need to partner like never before if we're going to make an impact. It was a productive workshop, but now we're at a point where we need to do the work. My take-away is that there are near-term opportunities like investing in talent that are quick wins all around. However, there are other topics that need much further shaping before co-investment is a win/win/win."
>
> *— David Parillo, Dow Chemical Company*

Breakout Discussions Focus Areas

Enabling Platforms for Polymer Characterization

Goal

Establish a 'trusted' suite of digital and experimental labs that can build scientifically trustworthy and actionable precompetitive research assets (high throughput synthesis experimental, characterization, metadata, ML techniques, simulation) for polymers for either soft matter or advanced material applications. These labs and their research assets will ultimately enable predictive structure-to-property modeling for sustainable technologies. This will be game-changing for discovery and in-market use of breakthrough polymers and materials.

Next Steps

- Identify the appropriate consortium model, associated funding streams, required finding level, and IP approach.
- Identify consortium members – polymer consumers (chemical companies) and analytical chemistry labs (academic labs and national labs) – and agree on the consortium's membership criteria, benefits, and outcomes.

Decarbonization through Recycling and Upcycling

Goal
Reduce carbon emissions by optimizing product life cycle through (1) developing new products that repurpose material from existing waste streams (upcycling) and (2) redesigning existing products (including the physical redesigns and the development of new modifiers and additives) to allow products to be returned to their base material state (recycling) in a less energy-intensive and wasteful way.

Next Steps
- Determine which companies are interested in funding a joint solicitation on this topic and the level of funding they prefer.
- Refine the scope of the topic to fit within the funding level that the companies desire.

Recycling Education

Goal
Increase the amount of recyclable material that is actually recycled by developing new, innovative programs and advancing education and access to recycling programs.

Next Steps
- **Testbeds:** Fund the design and implementation of new, innovative approaches to recycling education and implementation to increase the percentage of currently recycled material being recycled. Universities are one example of a uniquely interwoven community in which many processes and procedures can be designed in a reasonably centralized way. As such, a university (or similar type of close-knit community) can serve as a testbed for new recycling programs and educational approaches. Additionally, universities are the home to bright academic minds who can evaluate relevant aspects of psychology, availability of information, and physical infrastructure to enable meaningful ways to increase recycling.
- **Education programs:** There is a need for baseline education and broader availability of recycling programs. Many under-resourced communities do not have access to recycling programs and are not knowledgeable about materials that can or cannot be recycled. Increasing the availability of recycling programs and community education about what and how to recycle can vastly increase the amount of material recycled.

End-of-life Optimization and Workforce Needs

Goal
Develop pathways to foster connections between chemistry and data science by cross-training current undergraduates, graduate students, postdocs, and professionals and building teams that encourage greater knowledge exchange between chemists and data scientists.

Next Steps
- Develop a 7-week course for chemists on the basics of data science.
- Make the course available online to be leveraged by existing chemistry programs.

Conclusion

Many of the company representatives expressed a strong desire to perform further due diligence on the identified topics while also recommending additional companies and nonprofit organizations that may be interested in investing in these areas. UIDP will convene these organizations and may issue subsequent findings for consideration.

Appendix A: Workshop Agenda

Wednesday, November 9, 2022

1–1:10 p.m.	**Welcome** Anthony Boccanfuso, UIDP Gerard Baillely, Procter & Gamble
1:10–2:10 p.m.	**Workshop Charge** Lee Ellen Drechsler, Procter & Gamble David Berkowitz, NSF Peter Dorhout, Iowa State University In this opening session, NSF and the workshop co-chairs will lay out the intent of the event. Lee Ellen Drechsler will present on Procter & Gamble's interest in joint-funding solicitations, Peter Dorhout will discuss academic motivations for research in collaboration with industry, and David Berkowitz will share NSF's intentions and perspectives.
2:10–3:10 p.m.	**Non-US Models** BLaura McConnell, Bayer In this session, attendees will receive an overview of triple helix models for jointly funded solicitations employed by non-US entities like Horizon Europe and the UKRI. Following a framing discussion, attendees will be invited to discuss the models presented and which aspects would be beneficial to them.
3:30–4:30 p.m.	**Overview of the Funding Call Development Process** Lin He, NSF NSF Chemistry will offer a brief presentation on NSF funding mechanisms and key steps taken to develop a funding call. Participants will be asked to share where they see themselves fitting into the process and how they would like to fit into it in the future.
4:30–5:30 p.m.	**Models for Current Joint-Funding Solicitations** Graciela Narcho, NSF NSF (and specifically its CISE directorate) have strategically partnered with companies to jointly invest in solicitations in areas of mutual interest. How these programs are developed, funded, and administered can vary, and participants will learn more about these models and structures. Examples of topics include IP, funding level, funding mechanism, time scale, and role of the company in review and post award.
5:30–6 p.m.	**Pulse of the Participants** Travis Williams, University of Southern California Following an afternoon of presentations and discussions, hear the key takeaways from day one and offer your thoughts on what is left to be discussed on day two.

Thursday, November 10, 2022

8:30–9 a.m.	**Day 1 Reflections and Day 2 Charge** Lee Ellen Drechsler, Procter & Gamble Using yesterday's learnings, participants will have an opportunity to provide feedback on their appetite for pursuing joint-funding opportunities.
9–9:10 a.m.	**Introductions to Technical Area Breakouts** Tony Boccanfuso, UIDP
9:10–10:40 a.m.	**Technical Area Breakout Discussions** Participants are divided into small groups to recommend future research challenges that can be addressed in a precompetitive research environment.
11 a.m.–12:15 p.m.	**Technical Areas Ripe for Joint Funding Approaches** Facilitator: Stewart Witzeman, UIDP During this session, each breakout group will share their recommendations, and participants will collectively discuss the prioritization of research areas. Participants will also cover practical issues such as realistic timing, funding, topical areas, and other relevant topics that will allow for development of potential new funding programs.
12:15–12:30 p.m.	**Next Steps** Lee Ellen Drechsler, Procter & Gamble Peter Dorhout, Iowa State University

Appendix B: Participant List

Genara Andrade, DuPont

Craig Aspinwall, University of Arizona

Jason Azoulay, Georgia Institute of Technology

Gerard Baillely, Procter & Gamble

Jon Ballema, Chem Link

Stéphane Beaulé, Soprema Inc.

JoonHyung Cho, The University of Virginia

Scott Collick, DuPont

Christopher Cramer, UL Research Institutes

Zissis Dardas, Raytheon Technologies Research Center

Peter Dorhout, Iowa State University

Lee Ellen Drechsler, Procter & Gamble

Elizabeth Drotleff, The Ohio State University

Pete Ellingson, Procter & Gamble

Scott Fagan, PepsiCo

Ann Gabriel, Elsevier

Kamilah Gillispie, Procter & Gamble

Teri Gray, Provivi, Inc.

Bryan Haynes, Kimberly-Clark Corporation

Chris Hewitt, BASF

Ralph House, UNC Chapel Hill

Anneke Kaminski, Procter & Gamble

Anna Lis Laursen, IBM

Laura McConnell, Bayer

Richard Muisener, Evonik

Joel Nelson, Cargill

Justin Notestein, Northwestern University

Kimberly Ogden, University of Arizona

Amanda Palumbo, Dow Chemical Company

David Parrillo, Dow Chemical Company

Sacha Patera, Princeton University

Tuan Phan, Texas Southern University

Amy Prieto, Colorado State University

Deepa Shankar, UL Research Institutes

Sameer Talsania, PepsiCo

Jill Venton, The University of Virginia

Mulugeta Wayu, Tennessee State University

Travis Williams, University of Southern California

Hong Yang, University of Illinois at Urbana-Champaign

Yongfeng Zhao, Jackson State University

Workshop Observers

David Berkowitz, National Science Foundation

Anthony Boccanfuso, UIDP

Saul Gonzalez, National Science Foundation

Lin He, National Science Foundation

Morgan Jones-King, UIDP

Jorge Lamboy-Gonzalez, National Science Foundation

Kevin Leland, Halo Science

Tingyu Li, National Science Foundation

Kenneth Moloy, National Science Foundation

Graciela Narcho, National Science Foundation

Kristina Thorsell, UIDP

Caroline Trupp Gil, American Chemical Society

Naomi Webber, Lewis-Burke Associates LLC

Stewart Witzeman, UIDP

Appendix C: Pre-workshop Survey Results

As part of an NSF-sponsored workshop on **Aligning Interests in Support of Chemistry Research**, UIDP surveyed corporate members to determine their company's interest in and experience with university research that is jointly funded by government and industry. The survey consisted of nine questions, one of which was industry sector-related, five with set responses, and three open-ended questions. There were 22 total respondents, 14 of which are participating in the workshop mentioned above.

Investment and Interest in Collaborative Research: The respondent pool is highly invested in academic research, with 91% of the respondents currently making measurable investments in academic research and a similar percentage currently participating in government-sponsored grants. Of those not participating in government-sponsored research, the remainder previously participated in such projects. Similarly, 95% of respondents were interested in collaborative research with other companies, and 85% were interested in partnering with government agencies to co-invest in academic research.

Barriers to seeking government grants: Survey respondents were asked to rank-order the most significant barriers when seeking government grants with academic partners. For the total respondent pool, IP was the top issue, with time and resource commitment ranking second. Difficulty selling proposals to senior management and long timelines from application to funding were essentially tied as the next most significant issues. For the respondents participating in the workshop, the lack of relevance was a top issue, and difficulty selling management was a lower priority.

Additional Barriers: An open-ended question was asked seeking additional barriers not covered in the above selections. Among the issues mentioned were late involvement in seeking an industry perspective, IP issues that make working in other regions more attractive, relevance, and timeline issues. The full list of issues is given below.

Issue	Example Responses
Relevance	• Industry perspective included too late in the process, versus leveraging industry and academics to shape grant call and/or specific proposals. • Perspective from academia and government as to what types of research are valuable to each is challenging (i.e., finding a 3-way match where all parties are receiving value from the partnership). • The agency doesn't want to fund the things that are company's need/priority.

Issue	Example Responses
Timeline	• The timeline between notification of the award to submission deadline is often too short. Need more time to identify ideas, scout for external partners, get stakeholders aligned … and then write the proposal. Sometimes even in the proposal stage partici-pants need to negotiate on IP and other terms. • Timeline from funding opportunity announcement to deadline for submission of compelling applications • Often short decision times needed, if we are secondary on a proposal, this is a challenge to internally align, particularly if in-kind or cash support is needed. In addition, the long-term commitment needed for many grants is not in line with budget cycles.
IP	• In the U.S., the high cost of academic research together with IP rights challenges make it more attractive to fund research in other regions (e.g., EU)
Culture and other mis-matches	• Academic partners perceived to be more interested in area of expertise than in the “problem” to be solved, unless the project is linked to a start-up, which in turn provides an IP barrier to partnership. • Confusing landscape of academics and the number of people to deal with.

Specific Experience with Government Funding: In another open-ended question, respondents were asked to share experiences (both positive and negative) with government funding. An illustrative summary of responses follows:

- Positive experience with NSF IUCRC for early precompetitive research;
- Positive experience with NSF GOALI, but sometimes these programs lack faculty enthusiasm;
- Complexity of multi-party IP negotiations and associated time pressures associated with completing these agreements within the proposal timeline;
- The need for a sufficient ROI (meaning access to IP) to justify investment in joint R&D;
- Positive experience with national labs and NIST for enabling capabilities such as measurement or computing power needed to advance a field of research; and
- Problems with NSF SBIR reviews due to lack of relevance, inconsistency, and lack of feedback on proposals.

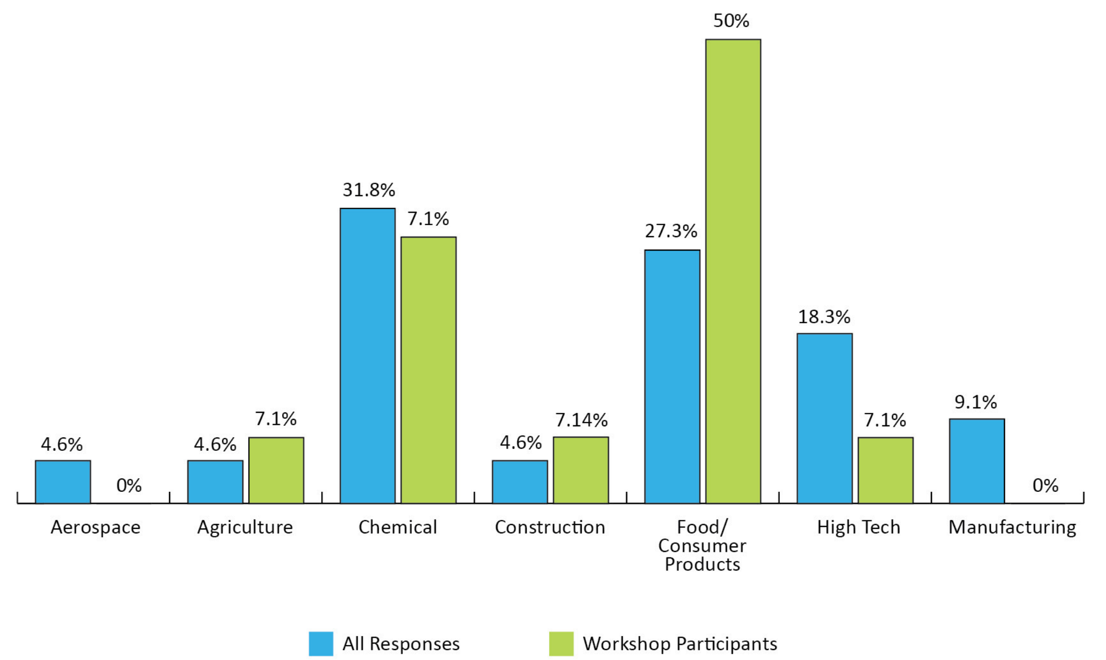
Areas for Possible Funding: Associated with the workshop mentioned above, survey respondents were asked for suggested focus areas for government support of industry-university research partnerships. Fifteen (15) suggested research ideas were proposed that could be categorized into five thematic areas.

- General issues around sustainability;
- Measurement and predictive tools;

- Low carbon technologies and plastic use/recycling;
- Impact of climate change on business and technologies; and
- Research and collaboration methods.

About the respondent pool: As expected from the survey topic, the respondent pool is highly tilted toward companies in the chemical sciences, as shown in the following table.

Which sector or technical field does your company most strongly associate with?



Appendix D:
Full List of Potential Breakout Topics

Low/zero/negative carbon intensity raw materials (could combine with enabling)
- Low/zero/negative carbon intensity raw materials
- Plastics/chemicals from waste streams or bio-based materials,

Recyclability and Degradation (could combine with plastics alternatives)
- Recyclable and/or biodegradable coatings for paper-based packaging
- "Easy to recycle" polymers
- Recyclable and/or biodegradable films
- Improved waste sorting/separation technologies
- Marine degradable plastics

Virgin plastics alternatives
- PCR/PIR
- Alternative to plastics for packaging

Others (could combine with Macrotrends)
- Gray water treatment and reuse
- Food cycle/waste management
- Packaging without labels
- Polymer innovation for soft matter or in-water use (precision design and manufacturing, biodegradable, superior functionality)

Enabling Technologies
- Carbon Capture/Utilization,
- Materials for Batteries
- Sustainable materials from lab-to-scale, including LCA and TMA
- Sustainable chemistries, predictive capabilities for new polymers, etc.
- Precision design and manufacturing, biodegradation predictive tools, structure/functionality models, and high-quality data.
- Sustainability, tool development (including analytical, computational, molecular biology)
- Sustainable raw materials and finished products for use in building envelope construction.
- Fundamental research on advanced materials and characterization; low-temperature plasma research

Macrotrends/Changes due to climate and need to accelerate knowledge transfer to achieve a sustainable future
- Hydrogen economy
- Electrification of the chemical industry
- Novel approaches to re-imagine agriculture to address climate change and planetary boundaries
- Development of technology for stronger and more durable structures to withstand the effects of climate change
- More sustainable chemical processes (energy efficiency, lower waste, etc.)

- Economic solutions for world-scale sustainability challenges like zero emissions, circular economy, and water scarcity that incorporate an array of voices across disciplines and sectors.
- Key to this will be considerations for reliability, availability, affordability, and scalability, despite short-term or long-term/fundamental research contributions
- Experiential learning opportunities to enable holistic thinking across sectors and disciplines to enable knowledge transfer to enable holistic thinking.

Need for dual-domain skills STEM + digital
- Tools to identify solutions faster, safer, and better, e.g., artificial intelligence, machine learning, and analytics
- Use of these tools will be essential to remain relevant in the chemical industry and to enter a new age of the chemical sciences.
- Data Science skills that incorporate essential chemical domain knowledge that are focused on solving materials, chemical, formulation, and process problems in a technically valid way.
- Being able to communicate with those in their field to help bridge different scientific disciplines and create more impactful collaborations.
- Talent able to do this is critical, and there remains a need for STEM talent with formal training or certifications in data science to act as bridges or translators.
- Ways to accelerate dual-domain skill talent development.

Need to accelerate knowledge transfer to achieve a sustainable future
- World-scale sustainability challenges like zero emissions, circular economy, and water scarcity will require an array of voices across disciplines and sectors to conceive economic solutions at scale to have real impact.
- All participants will be required to think holistically and differently as they approach their role in the innovation ecosystem.
- Key to this will be considerations for reliability, availability, affordability, and scalability, despite short-term or long-term/fundamental research contributions
- To achieve these goals, there remains a need for experiential learning opportunities to enable holistic thinking across sectors and disciplines.
- What experiential learning opportunities will help to enable knowledge transfer to enable holistic thinking?

References

[1] *The precise definition of precompetitive research can vary by industry sector, but generally speaking, precompetitive research is early stage, and it is unlikely that a product or service will flow directly from it. Generally, precompetitive research is Technology Readiness Level (TRL) 1-3. Source: 2022, UIDP Quick Guide, Precompetitive IP and Consortia. Accessed Feb. 3, 3032. uidp.org/publication/precompetitive-ip/*

[2] *NIST Awards Funding for Educational Programs on a Circular Economy to Reduce Plastic Waste. (2022, September 20). NIST. Retrieved March 8, 2023, from nist.gov/news-events/news/2022/09/nist-awards-funding-educational-programs-circular-economy-reduce-plastic.*

[3] *ACC. 2021. 2021 Guide to the Business of Chemistry. americanchemistry.com/chemistry-in-america/data-industry-statistics/resources/2021-guide-to-the-business-of-chemistry*

[4] *NSF/VMware Partnership on the Next Generation of Sustainable Digital Infrastructure (NGSDI) program solicitation: nsf.gov/pubs/2020/nsf20594/nsf20594.htm*

[5] *National Artificial Intelligence (AI) Research Institutes program solicitation: nsf.gov/pubs/2022/nsf22502/nsf22502.htm*

[6] *Resilient & Intelligent NextG Systems (RINGS) program solicitation: nsf.gov/pubs/2021/nsf21581/nsf21581.htm*

[7] *National Academies of Sciences, Engineering, and Medicine 2022. The Importance of Chemical Research to the U.S. Economy. Washington, DC: The National Academies Press. doi.org/10.17226/26568*

[8] *Each breakout discussion included multiple sub-topics; the full list with subtopics can be found in Appendix D.*

Copyright and Disclaimer
UIDP materials, which include publications, webinars, videos, and presentations, reflect an amalgamation of the experiences and knowledge of those who participate in UIDP activities. The views and opinions expressed in UIDP materials do not necessarily reflect the official policy or position of any individual organization. At no time should any UIDP materials be used as a replacement for an individual organization's policy, procedures, or legal counsel. UIDP is not a lobbying organization, and UIDP materials are not intended to influence government decisions.

All rights reserved. This UIDP member-only publication cannot be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of UIDP.

Additional written permission may be granted to members, non-members, and/or participants in certain UIDP events. Additional permissions can be found in the UIDP materials to which they pertain.

For permission requests, write to UIDP at:
1705 Richland Street, Suite G, Columbia, SC 29201.

Copyright © 2023 by University Industry Demonstration Partnership (UIDP)
04/23

uidp.org

Strengthening
University-Industry
Partnerships