Testimony of
Dr. Kelvin Droegemeier, Vice President for Research, University of Oklahoma
and Past Vice Chair, National Science Board
before the Senate Committee on Commerce, Science, and Transportation
May 11, 2016

INTRODUCTION

I thank Chairman Thune, Ranking Member Nelson, Senators Gardner and Peters, and other committee members for the opportunity to testify on the vital role of the science and engineering enterprise to our nation's competitiveness. My name is Kelvin Droegemeier and I am Vice President for Research, Regents' Professor of Meteorology, and Weathernews Chair Emeritus at the University of Oklahoma. I am also, as of yesterday, immediate past vice-chair, of the National Science Board (NSB, Board) which establishes policy for the National Science Foundation (NSF) and serves as an independent body of advisors to both the President and Congress on matters related to science and engineering research and education. I am testifying today as Vice President for Research at the University of Oklahoma, although my remarks are also shaped by my dozen years on the Board.

The prospect of a new COMPETES Act comes at a time of extraordinary possibilities for science. The NSF-sponsored Laser Interferometric Gravitational Wave Observatory (LIGO) recently opened new windows on our understanding of the universe and is creating an entirely new area of research into gravitational wave astronomy. Clustered Regularly Interspaced Short Palindromic Repeat (CRISPRs) are helping us cheaply and precisely edit the human genome to find ways to prevent and cure insidious diseases such as cancer, Alzheimer's, diabetes, and HIV/AIDS. And the potential for using big data to expand the scope of our research and to revolutionize how we do science is now before us. The NSF has bold plans to lead the science enterprise to new frontiers. The Foundation envisions supporting research on how genes interact with the environment, on interactions between people and technology, and on the rapidly changing Arctic. The opportunities before us are incredible, all the more so when you think of the pace at which scientific advancement has accelerated during the past few decades and the tools and level of understanding we now have.

Science and engineering are now truly a global enterprise. Other countries have followed the U.S. lead, and are emulating our model, investing heavily in S&E research, education, and workforce development. China, for example, has nearly tripled the number of high performance computing (HPC) systems on the most recent "TOP500" list, while the number of systems in the United States has fallen to the lowest point since 1993. We know how to meet this challenge. The recent National Academies report, Future Directions for NSF Advanced Computing

Infrastructure to Support U.S. Science and Engineering in 2017-2020, for instance, outlines a framework to ensure continued U.S. leadership. The question before the U.S. is whether we have the will to capitalize on these emerging opportunities.

Over the past decade, NSF's research budgets have been nearly flat in real dollars. The Federal government now invests less of its budget in research and development (R&D) than at any time since Sputnik was launched. Over the longer term, this will need to change if we want to remain world leaders in S&T. In the near term, I am mindful of the enormous challenges posed by the slow-but-steady growth of mandatory spending programs. Yet despite these fiscal realities, I am also hopeful, in a way that I have not been since the National Academies undertook the *Rising Above the Gathering Storm* report and Congress responded with the original COMPETES Act. This committee has already addressed one of the greatest long-term threats to American innovation: You've made science bipartisan again, countering rhetoric that has at times made the research community feel under siege.

My testimony offers a three-pronged approach to leveraging our existing R&D resources. First, we need to focus on where the Federal Government adds unique value. This includes the basic research that is generally not conducted by the private sector. Second, we need to maximize the impact of our investments, particularly by decreasing regulatory burdens and increasing the effectiveness of commercialization activities. Finally, we need to redouble our efforts to develop the workforce of tomorrow. For decades, our country has reaped the returns on huge investments in the space race, especially in terms of our science and engineering workforce. We can only address the oncoming "silver tsunami" of retirements by leveraging the full breadth of our nation's talent pool.

IMPORTANCE OF DISCOVERY RESEARCH

In the waning days of World War II, President Roosevelt, recognizing that wartime cooperation between the Federal Government and scientific community had contributed to the U.S. victory, asked Vannevar Bush how the Government could promote scientific progress in the postwar period. That report, *Science – The Endless Frontier*, called for the creation of what would eventually become NSF. Bush stressed the essential role of the Federal Government in funding basic—or "discovery"—research and cultivating the Nation's "scientific talent."

Discovery research uses the scientific method to understand the natural universe, and it is the DNA from which new innovations emerge. That DNA, representing thousands of discoveries across all science and engineering disciplines, can be assembled, refined, set aside for a time until other advances call upon it, and re-used in an almost infinite number of ways to produce outcomes with profound benefits for society. Nowhere is this more evident than in current and rapidly evolving national security challenges. Discovery research has fueled advances in image processing, electrochemical sensing, and data mining. These advances have, in turn, led to the rapid creation of field-deployed technologies for enhancing security in airports, improved safety of our soldiers, and the ability to fight next generation cyber-attacks.

Federally-funded discovery research is just one vital component of our Nation's highly interdependent innovation ecosystem. Total national investment in R&D includes funding by the

Federal Government, states, colleges and universities, and the business and nonprofit sectors. Today, businesses fund about two-thirds and perform nearly three-quarters of R&D in the United States. Because returns on investments in basic research are unpredictable and may take years, if not decades, to materialize, the business sector focuses largely on development. In 2013, businesses directed about 78% of their R&D resources toward development, compared to just under 16% toward applied research and about 7% towards basic research.

The Federal Government, and NSF in particular, plays a critical, complementary role by supporting discovery research. NSF's motto is "Where Discoveries Begin," and NSF is the only federal agency whose mission is to promote the progress of discovery research in *all* fields of science and engineering. By investing in early stage research in all scientific fields, NSF lays the knowledge foundation that makes possible the application-oriented science pursued at other agencies and the technological innovations developed by the nation's businesses. I fully agree with Senator Peters, who said "Basic R&D is the seed corn of our economy, and the innovation that it generates helps build new industries, increase productivity, and enhance American competitiveness."

NSF-funded research not only helps our Nation tackle the societal challenges of today and tomorrow, but also provides the U.S. with a competitive advantage in a globally competitive marketplace. In April of this year, Bill Gates wrote that "Government funding for our world-class research institutions produces the new technologies that American entrepreneurs take to market." Recognizing this, numerous developed and emerging economies, including South Korea, India, Brazil, and especially China, have ramped up their investments in R&D. Indeed, China is now second in the world in R&D, having surpassed Japan and drawn equal with the European Union. While science and technology is not a zero-sum-game--innovations in China can improve the life of Americans--it is important that we remain a global leader. Continued U.S. leadership in science will ensure that future generations of Americans will live in a secure and prosperous country.

NSF's ability to invest in discovery research in all fields of science, including the social, behavioral and economic (SBE) sciences, is central to this competitive advantage. The United States is one of the only countries in the world that makes significant investment in SBE sciences. NSF-funded research into understanding individual and societal human behavior often sits at the interface between technology and the people who use it. If we do not understand why some people ignore storm warnings or the factors that support economic development or drive the activities of rogue states and terrorists, we are crippling the ability of our Country and every individual in it to reap the full benefits that scientific and technological progress has to offer.

The broader point is that the knowledge gained from discovery research in all disciplines strengthens our innovation ecosystem and ensures that the United States is maximally prepared for an unpredictable future. Because we do not know *a priori* how we will solve the great challenges of the 21st century or even what all of these challenges will be, it is imperative that we combine robust support for core research in all fields of science with interdisciplinary and collaborative initiatives. As the National Academies wrote in its 2014 report, *Convergence*, the "merging ideas, approaches, and technologies from widely diverse fields of knowledge at a high level of integration is one crucial strategy for solving complex problems and addressing complex intellectual questions underlying emerging disciplines." Said another way, some of the most societally important and intellectually challenging problems occur not within disciplines, but at the boundaries among many disciplines. I have included two examples that illustrate this point:

1. Discovery research at the interface of the biological and mathematical sciences is addressing important human health challenges. The spread of infectious diseases from wildlife to humans is on the rise, with this year's Zika virus and last year's historic Ebola outbreak as recent examples. Factors that affect such outbreaks include the density of human and wildlife populations, changes in land use, and human behavior. A joint initiative between NSF's Division of Mathematical Sciences and the National Institute of Health's National Institute of General Medical Sciences has supported work on Ebola, fostering collaborative research projects that leverage the contributions of disease ecologists, epidemiologists, mathematicians and economists to better understand this and other rapidly evolving infectious diseases.

(2) Nearly a decade ago, NSF--recognizing that the electricity sector was insufficiently focused on security--invested in early stage research on how to design and build resilient cyberinfrastructure for the power grid. This research, sponsored by NSF's Computer and Information Science and Engineering (CISE) Directorate, has since been carried forward with funding from the Department of Energy's Office of Electricity Delivery and Energy Reliability (DOE-OE) and the Department of Homeland Security Science and Technology Directorate. Today, the Trustworthy Cyber Infrastructure for the Power Grid Project (TCPIG) is collaborating with national laboratories and the utility sector to improve the design, security, safety, and resiliency of the U.S. power grid. Thanks to these successive federal investments, the group's technologies are being piloted in real utility environments and their work has become foundational technology for three start-up companies.

Our national innovation ecosystem is only as strong as its component parts. In addition to the threat posed by efforts to dramatically decrease or eliminate funding for the SBE sciences, our innovation ecosystem is equally weakened by the challenges facing our Nation's colleges and universities. The majority of NSF-funded discovery research is performed by universities and colleges, and these institutions are equally important in educating and training the next generation of STEM-capable workers. The NSB's recent policy-focused Companion Brief to *Science and Engineering Indicators 2016* entitled, *Higher Education as a Public and Private Good*, describes how declines in federal support for R&D, waning state funding for public research universities, and tuition increases are converging to create a "perfect storm." This storm threatens to undermine the ability of these institutions to perform their vital research and education missions.

Reduce administrative burdens and other drains on research dollars

The current funding challenges only serve to underscore that we must ensure that taxpayer dollars are spent wisely and efficiently. NSF ensures that it invests in only the best scientific projects using two evaluation criteria--*intellectual merit* and *broader impacts*. NSF's merit review process is highly emulated and widely considered the best in the world. Despite the impressive track record of discoveries produced by NSF's merit review system, NSF and the NSB regularly strengthen and clarify it. For example, in 2011 the NSB re-examined the intellectual merit and broader impacts criteria, [1] and in 2013 NSF launched the *Transparency and Accountability Initiative* to strengthen Agency efforts in transparency and accountability around the merit review process, and the Board adopted a formal policy resolution in May of 2015. [2]

While transparent, merit-based competition is a powerful incentive toward the efficient use of taxpayer dollars, it is not enough by itself. At a time of fiscal challenges and with low funding rates at many Federal agencies, we also need to ensure that Federal dollars are spent efficiently, without fraud, abuse, or waste. This includes reducing the administrative workload placed on federally funded researchers at U.S. institutions. As detailed in the Board's 2014 report and the subsequent National Academies' report, there are numerous opportunities to address unnecessary regulations that interfere with the conduct of science in a form and to an extent substantially out of proportion to the well-justified need to ensure accountability, transparency and safety.

As a vice president for research at a tier-1 comprehensive research university, I can attest to the growing number of unfunded compliance and reporting requirements and their deleterious impact on research. I hasten to add that researchers and university research leaders understand and appreciate the importance of appropriate compliance rules and regulations. The academic enterprise rests on the integrity of its participants. However, the important issue at hand is the extent to which aggregated regulations are appropriately structured, implemented, and evaluated with regard to their effectiveness and unintended or unnecessary consequences. It is also important to note that this is not just a Federal problem. States, accrediting organizations, and universities themselves all contribute to administrative burdens.

I am heartened by the attention this committee and others in Congress have paid to these studies and, based on legislation already introduced, I am confident that any comprehensive legislation written by this committee will address these concerns in a bipartisan way. I hope that attention will also be given to the forthcoming *Part II* report from the Academies' Committee on Federal Research Regulations and Reporting Requirements. I am also pleased to report that the NSF has been acting independently to implement some of the recommendations from the Board's report. Great improvements have been made in standardizing and simplifying some of NSF's reporting requirements and in avoiding errors in grant submission. In addition, a number of pilot programs are also underway to streamline the proposal process (for instance, exploring just-in-time budget submissions).

While I am sensitive to the budget constraints faced by legislators, I feel it is incumbent on me to remind you that unpredictable funding is also a source of inefficiency. Simply put, continuing resolutions and unknown funding bring with them delays that cost money. This is especially true for NSF's Antarctic program and our large facilities. Congressional support for long-term strategic plans, including community-driven decadal surveys and prioritization processes, can help reduce uncertainty in this regard.

One of the biggest challenges facing NSF and basic research generally is the balance between high-risk, high reward research and delivering tangible returns to taxpayers. I urge the committee to embrace the complexity of our enterprise, and to understand that these long-term basic research investments must be undertaken by the public sector. In my view, the level of oversight should be linked to the level of risk in our investments. Science should never be risk free, and oversight activities --- never free --- should always have a positive return on investment.

NSF is keeping this in mind as it implements the recommendations in the recent National Academy of Public Administration (NAPA) report, *National Science Foundation: Use of Cooperative Agreements to Support Large Scale Investment in Research*. This is proving a timely tool to improve NSF's oversight of large facilities. The NAPA committee rigorously addressed its charge, which was jointly developed by the NSB and NSF Senior Management, identified areas where NSF can improve, and provided recommendations that will strengthen our oversight of facilities. The Board and NSF Senior Management are in general agreement with the Panel's recommendations.

The Foundation's leadership and I appreciate Congress' shared recognition that wise stewardship of taxpayer dollars is essential to the progress of science. In that vein, I note that while the NAPA report described a need for heightened accountability, it also concluded that Cooperative Agreements (CAs) are an appropriate mechanism for NSF to use for designing, constructing, and operating large facilities. NSB endorses this conclusion and I have repeatedly seen how NSF uses these cooperative tools to address the Board's concerns.

With respect to the NAPA report, I urge the committee to set goals and expectations while preserving an appropriate level of flexibility with respect to pre-award cost analyses, audits of incurred costs, and management fees. I believe that prohibiting the use of management fees in cooperative agreements (as allowed by OMB regulations) would ultimately result in the public paying more for less research. Even codifying current practice risks hampering opportunities for additional efficiencies. For instance, mandatory incurred cost audits for large facility construction projects can cost millions of dollars that would have otherwise gone to funding grants. It is more sensible, and appropriate, to conduct such audits only when project risk warrants it. NSF's recent improvements in large facilities management, recognized by NAPA as "tremendous efforts," have to a great extent sought to realize a risk-appropriate level of oversight.

In this vein, I especially commend the Academies' recommendation to ensure balance between Inspectors General's twin mandates. The Inspector General Act of 1978 charged leadership in preventing fraud and abuse ***and*** in promoting "economy, efficiency, and effectiveness in the administration of programs." I believe the associated recommendations regarding transparent reporting of costs and recoveries, interpretation of agency policies, and risk-based methodology can be helpful in ensuring balance between these mandates.

Finally, I remind the committee that in many cases it is worth paying for transparency and oversight. Inspectors General have delivered tremendous returns to taxpayers, as have regular audits, and NSF's Large Facilities Office (LFO). NSF is already pursuing the NAPA panel recommendation that it add training for program officers and add personnel to the LFO. These improvements are necessary, but they cost money. While NSF continues to process a larger number of more complicated grants, its Agency Award Management and Operations (AOAM) account has remained flat. Even the most efficient handling of grants and oversight of projects requires resources, and I encourage the committee to support increases to this account. Without increases, I worry that these costs could degrade or reduce NSF's investments in research and education.

STEM education and STEM-capable workforce

Investments in STEM education go hand-in-hand with investments in discovery research. Both are vital to continued U.S. scientific leadership, economic competitiveness, and national security and prosperity. Furthermore, to compete and win in the current global environment, the nation needs flexible STEM-capable workers at every education level. The days in which STEM skills were necessary only for occupations traditionally classified as "science and engineering" (S&E) are over. We must recognize this breadth and heterogeneity of the STEM workforce within the framework of America COMPETES.

Workers who hold a STEM degree, work in a STEM job, or who use significant STEM knowledge and skills in their jobs are part of the STEM workforce. Of course, the STEM workforce includes scientists and engineers who further scientific and technological progress through research and development (R&D). In addition, workers in non-R&D jobs who use STEM knowledge and skills and those in technically demanding jobs who need STEM capabilities to accomplish occupational tasks are also part of this workforce. Far from being a monolithic, homogenous group, the STEM workforce is comprised of workers with different educational qualifications who are employed in a wide range of fields and careers. All of these jobs have one essential characteristic in common: They are the better-paying jobs that have driven recent economic growth.

In 2013, over 13 million U.S. workers were employed in an occupation classified as "S&E" or "S&E-related". Yet in a survey of individuals with at least a four-year degree, including many working in sales, marketing, and management, almost 18 million reported that their job required at least a bachelor's degree level of S&E expertise. In fact, in 2013, the number of non-S&E jobs that require a bachelor's level of S&E skills surpassed the number of traditional S&E jobs for the first time, demonstrating that the application of S&E knowledge and technical expertise is widespread across the U.S. economy.

In our knowledge- and technology-intensive economy, STEM skills are also required for many in-demand, well-paying careers that are available to workers with less than a bachelor's degree. These jobs, which combine conventional literacy with technical expertise, are concentrated in information technology (IT), health care, and skilled trades. Career and technical education in high schools, community colleges, and certification programs provide vital pathways into this "technical STEM workforce." When these workers are included, there may be as many as 26 million jobs in the U.S. that require significant STEM knowledge and skill in at least one field. This represents nearly 20% of all U.S. jobs. Demand for these jobs is distributed nationwide, providing a gateway to opportunity for a segment of the U.S. workforce that has been hard hit by transformations in the domestic and global economy. As Anthony Carnevale, director of the Georgetown Center on Education and Workforce, noted, "There's a new middle. It's tougher, and its takes more skill."

In addition, the new COMPETES framework should recognize that STEM education and training is no longer just for our nation's young people. To keep pace with the changing global S&E landscape, the U.S. needs to ensure that incumbent workers (both those currently in STEM and those who would like to enter it) have opportunities to upskill and reskill. Given the rapid pace of scientific and technological change in the twenty-first century, STEM-capable workers will need to periodically update their skills. To prepare students and workers for this environment that will demand lifelong learning and reskilling, we must ensure that our STEM education programs create a foundation on which individuals can continuously scaffold new competencies and knowledge; and that government, educational entities, and industry each do their part to make such reskilling and upskilling accessible and affordable.

At the same time that the COMPETES framework recognizes the importance of STEM skills for an ever wider swath of the U.S. workforce, we must recognize that an innovation economy and continued U.S. global leadership cannot be secured through STEM education alone. Arts and humanities education is an essential complement, teaching students interpretive and philosophical modes of inquiry, honing communication and writing skills, fostering multicultural and global understanding, and encouraging an appreciation of history, aesthetics, and the human experience. As a 2013 American Academy of Arts and Sciences report highlighted, study of the humanities and arts develops both critical perspective and imaginative responses, ways of thinking that contribute to inventiveness.

While adopting a broader vision of STEM education and workforce training, the U.S. must continue to support the core of its advanced R&D workforce, doctoral degree recipients. NSF facilitates the education and training of the next generation of scientists and engineers (graduate students as well as postdoctoral researchers) by funding grants to support their research and training. Flagship programs such as the NSF Graduate Research Fellowship, which has produced several Nobel Laureates over the past six decades, are seminal to U.S. competitiveness and STEM workforce development. The American system of doctoral education is widely considered to be among the world's best, as evidenced by the large and growing number of international students—many of them among the top students in their countries—who choose to pursue the doctoral degree at U.S. universities. However, the continued preeminence of U.S. doctoral education is not assured. Other nations, recognizing the contributions PhD recipients make to economies and cultures, are investing heavily in doctoral education.

Doctorate recipients are the best avenue for transferring basic research discoveries into the technology and biotechnology economies. They begin careers in large and small organizations, teach in colleges and universities, and start new businesses. Among individuals with S&E doctorates, the proportion working in the business sector (46%) is similar to the proportion working in the education sector (45%). As these data show, doctoral education develops human resources that are critical to the nation's progress—scientists, engineers, researchers, and scholars who create and share new knowledge and new ways of thinking that lead, directly and indirectly, to innovative products, services, and works of art. In doing so, PhD recipients contribute to a nation's economic growth, cultural development, and rising standard of living.

The COMPETES framework should recognize the importance of this group to our nation's competitiveness and work toward ensuring that careers in R&D--including those in universities—are attractive to the next generation of scientists and engineers. From the Federal Government standpoint, one key component of this is steady, predictable funding for scientific research. Unpredictable changes to Federal funding for research and "boom-bust" cycles can significantly disrupt the balance between the number of STEM PhDs and the availability of permanent jobs where PhDs can use their specialized training in the academic sector.

The foundation for building this STEM-capable workforce begins with quality primary and secondary STEM education. Almost all of today's STEM jobs require completion of some additional STEM education/training after high school, whether that be a certificate program, coursework, or a degree. K-12 science and math education is therefore critical to preparing students to pursue post-secondary STEM education/training. At a time when more and more individuals in a variety of jobs, including those that were not historically seen as STEM, require STEM capabilities, we need to ensure that all our K-12 students achieve basic STEM literacy. As a nation, our goal should be STEM literacy for all, rather than just for some.

The COMPETES framework should also support continued efforts to attract and retain women and underrepresented minorities in STEM. Although there are some encouraging trends - such as improved high school completion rates, the increasing number of Hispanics earning S&E bachelor's degrees, and an increase in the proportion of S&E PhDs earned by women, there is still much more to be done in this arena. The long-term strength of our workforce requires that the full range of STEM career pathways be available to all Americans. This is a matter of economic opportunity -- as I mentioned, STEM jobs are among the highest paid and most recession-resistant of all jobs in the U.S. economy. It is a matter of the robustness of our science; research demonstrates that diverse perspectives are critical to the enterprise. Indeed, the research enterprise is impoverished when individuals from underrepresented groups leave STEM fields or fail to select them to begin with. It matters even more urgently in light of rapidly shifting national demographics, given that Hispanic, blacks, women, and Alaskan/Native students are not obtaining S&E degrees in numbers commensurate with their representation in the U.S. population.

NSF is poised in the coming years to make substantial progress in addressing this. Earlier this year, NSF rolled out Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES), its most ambitious broadening participation endeavor to date. Building upon its history of funding research into what works in STEM education and facilitating its translation into practice, the multi-year INCLUDES program is designed to help take insights and best practice and bring them to scale. Other initiatives that support the development of a more diverse STEM workforce include the Historically Black Colleges and Universities Undergraduate Program (HBCU-UP), the Tribal Colleges and Universities Program (TCUP), and the Louis Stokes Alliance for Minority Participation. As evidence increasingly shows that research experiences early in college are critical to student retention in STEM, the Research Experiences for Undergraduates (REU) program is also poised to play a vital role to bringing in and retaining women and underrepresented minorities.

Innovation and research commercialization

Our nation's innovation ecosystem is the lifeblood of our economy and quality of life. The NSF plays a crucial role in that ecosystem by supporting fundamental research in *all* fields of science and engineering and creating the workforce of the future. Private industry relies on the new knowledge created by basic research to develop new and innovative products and services.

The research that taxpayers have supported for over 60 years through the NSF has advanced our knowledge, developed and supported hundreds of thousands of scientists and engineers, fueled our economy and transformed our way of life by the technologies and processes derived from basic research.

Several NSF initiatives play a vital role in moving innovations from the lab to the marketplace. NSF's I-Corps program seeks to accelerate commercialization and entrepreneurial education. For example, research funded by NSF's Social and Behavioral Sciences on the content of weather advisories and warnings, the communications channels used, and on how residents comprehend specific advisories and warnings highlighted that use of tailored messages is critical to saving lives. Professors Carol Silva and Hank Jenkins-Smith – both Political Scientists at the University of Oklahoma – have conducted groundbreaking research in these areas. Building off their NSF-funded basic research, Dan O'Hair and his team at the University of Kentucky are, with the help of an NSF I-Corps grants, exploring ways to commercialize their research on tailored storm warning communication. This is both a commercial and humanitarian opportunity, and one that highlights how fundamental research—in this case in the social sciences—can help catalyze new businesses.

NSF's Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program seeks to transform scientific discovery into societal and economic benefit by catalyzing private sector commercialization of technological innovations. The program increases the incentive and opportunity for startups and small businesses to undertake cutting-edge, high-quality scientific research and development. NSF is working to better connect the I-Corps program with existing SBIR/STTR programs.

The agency's EPSCoR program ensures that all geographic regions in the U.S. contribute to S&E research and education by providing research capacity-building funding. EPSCoR also plays an important role in economic development across this country. I would never have been able to start my company, Weather Decision Technologies, were it not for EPSCoR, which helped support one of NSF's first Science and Technology Centers. This center, which I directed at the University of Oklahoma, pioneered a new science of computer-based prediction of thunderstorms and led to the founding of the company, which today employs over 80 people.

Finally, I wish to highlight the importance of academic-corporate-government partnerships in the innovation ecosystem. Research universities are important engines of local, regional and national economic development. However, in spite of the dramatic increase in private investment in R&D over the past 20 years, very little of this increase has come to universities.

One of the primary barriers to greater university-industry partnership is that Federal tax laws place significant restrictions on universities' ability to negotiate intellectual property terms at the front end of a contract. Lack of certainty about cost makes it difficult for private companies to create business plans, based upon intellectual property licenses from universities that are acceptable to corporate leadership and shareholders.

In its recent report *Restoring the Foundation,* the American Academy of Arts and Sciences recommended modifications to Federal tax law to remove impediments to corporate-academic partnerships. The America COMPETES re-authorization would do well to consider this issue and unlock the potential of corporate-academic collaboration.

CONCLUSION

Just over 65 years ago, James Conant, the first Chair of the National Science Board, wrote, "No one should expect to be able to assess in a short interval of time the value of the money spent on scientific investigations. Even in the field of applied science, research is in the nature of a long-term investment." Having just concluded twelve years on the Board, I am more convinced than ever that this long-term national investment in fundamental science, research infrastructure, and STEM education is essential to our future health, security, and prosperity. In a world where science today has bearing on almost every aspect of our lives, from national security and global economic competitiveness to our health, quality of life and future workforce needs, NSF continues to open new frontiers by balancing its longstanding "grass roots" vision of science with an agency-wide commitment to fund research addressing our nation's priorities.

Our challenge now is to find ways to sustain the U.S. science and engineering enterprise at a time when budgetary pressures are limiting our resources. But we can't let that stop us from continuing to dream big—America's greatest asset is our creativity and freedom to explore. We need to leverage NSF resources with interagency collaborations that extend the reach and yield of NSF investments and encourage academic-industry partnerships. We need to maximize the dollars that go to research by reducing administrative burdens. We need to build on successful NSF programs that spur the transfer of knowledge to commercialization. And we need to remove obstacles and create opportunities to develop the STEM-capable U.S. workforce required for an increasingly multi-polar and knowledge-intensive world.

My colleagues in the scientific community and I commend this bipartisan effort, and urge your continued support of NSF, the research enterprise, and the nation's bold – but essential – quest to advance the "endless frontier."

---

[1] http://www.nsf.gov/nsb/publications/2011/nsb1211.pdf
[2] http://www.nsf.gov/od/transparency/transparency.jsp