American Competitiveness: *The Role of Research and Development*

Testimony before the U.S. House Committee on Science, Space, and Technology

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Chairman Smith, Ranking Member Johnson, Members of the Committee – thank you for the opportunity to testify before you today on *American Competitiveness: The Role of Research and Development*. Texas Instruments has enjoyed a close relationship with this committee for many years given our mutual interest in research and STEM education. I applaud your convening this important hearing so early in the Congress.

I am pleased to testify alongside Dr. Charles Vest and Dr. Shirley Ann Jackson, who have each done so much to draw attention to innovation issues. One of TI's founders, Erik Jonsson, graduated from Rensselaer Polytechnic Institute in 1922, illustrating that even many decades ago, great educational institutions trained the entrepreneurs that create entirely new industries.

I have been asked to address the industry perspective on research and development (R&D). I appear on behalf of the Task Force on American Innovation and as a board member of the Semiconductor Industry Association. I will draw heavily on my more than 30 years with Texas Instruments in my testimony.

If I leave you with one message today, it is this: federal funding of fundamental scientific research is critical to our nation's continued competitiveness, economic growth and workforce development. It will shape our future. It will launch new industries, undergird our scientific and engineering infrastructure, produce our next Nobel Laureates, ensure unparalleled academic excellence of our universities, and provide an economic future for the nation. It is not a switch that can be turned on and off.

A fundamental theme will be the critical feedback loop between industry, universities, and government as a key characteristic of the U.S. innovation ecosystem. Innovation is a shared responsibility, and government plays an essential catalytic role in making it happen. Economists attribute as much as half of economic growth over the last fifty years to innovation, scientific, and technological progress – much of which would not have occurred without federal investments in university-based research.

TI is the nation's second largest semiconductor manufacturer with more than 100,000 innovative products to help our 100,000 customers unlock the possibilities of the world as it could be –

smarter, safer, greener, healthier and more fun. We make chips that go into everything from consumer electronics to automobiles, medical devices, motor controls – just about anything with an on and off switch. Innovation has been a cornerstone of our 83-year history. In 2012, TI invested nearly $1.9 billion in R&D, a figure that grew 9 percent compared with 2011, even as our annual revenue fell between the two years. This might seem counterintuitive. However, over the years I have observed that companies that invest during a downturn are better positioned for the recovery.

The same concept applies to countries. If we want the United States to remain the leader in cutting-edge technologies, in knowledge-based industries, and to create the related high-paying jobs and new companies, we must prioritize investment in research.

My testimony today focuses on five areas: 1) types of R&D and funding sources, 2) industry approach to R&D, including model private-public partnerships, 3) global R&D incentives, 4) breakthrough technologies that might be realized, and 5) policy implications.

R&D types and funding sources

The term "R&D" is often used inseparably, but there is an important distinction between research and development. The days of the Bell Labs model of large-scale, corporate-funded exploratory research labs are long gone. Companies invest largely in development, and to a lesser extent in research. Development focuses on executing the next iteration of existing products and new products. This is particularly true in the high-technology sector. Companies must continually innovate or become obsolete.

Research can be further segmented into fundamental (or basic) and applied. Fundamental research is exploratory in nature and conducted to understand basic principles without necessarily having a commercial purpose in mind. The benefits are broad, societal, and potential payoffs are further in the future. Applied research is undertaken with a specific end, an attempt to solve a practical problem in a much nearer term.

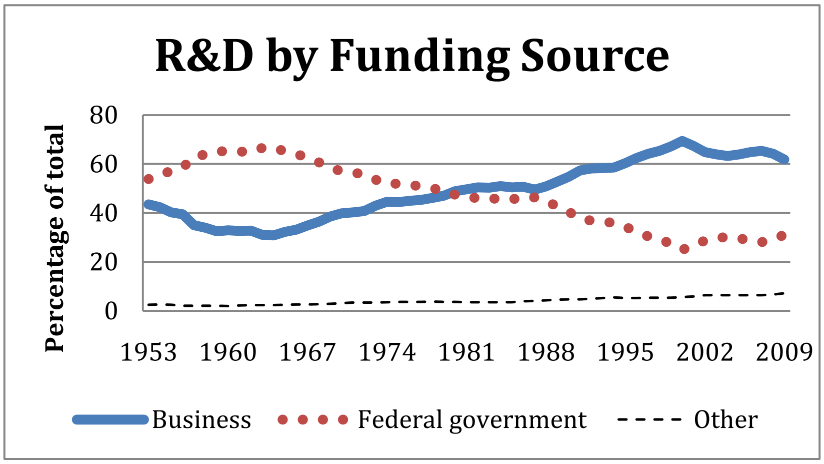
Historically, the federal government has been the primary source of basic research funds and supports higher-risk, exploratory research that universities are best able to conduct. It is basic research upon which all other R&D rests, including that performed by the private sector.

Individual companies or consortia are not able to perform basic research on the scale or sustained level of the federal government. Basic research requires patient capital. It can take 5-15 years or more to bear commercial results, if at all. However, when it does pay off, those payoffs to our society and to our economy are spectacular and many times, in unanticipated or unintended ways. And sometimes the pay back extends for years as researchers find new and innovative applications for these discoveries. If you look at examples of federally funded basic research outcomes – the laser, GPS, the Internet, and semiconductor advances – all have revolutionized the world and how we interact with it. The fundamental research undertaken on these technologies began 50 to 60 years ago.

The private sector, on the other hand, generally focuses on later stage research and development. As the Congressional Joint Economic Committee has stated, "Despite its value to society as a whole, basic research is underfunded by private firms precisely because it is performed with no specific commercial applications in mind."

Industry invests some $270 billion in R&D, but it focuses mainly on the "D" – the development of technologies that can be brought to use and markets in the near term. While it is essential to the innovation process, the long-term horizon of most scientific research conducted at universities, which perform a majority of basic research, is viewed by industry as too risky for significant private sector investment. This is why the federal government's support for basic scientific research is critical to innovation.

In the United States, expenditures in R&D have largely remained stagnant for the last 30 years as measured as a percent of GDP. U.S. national R&D from all funding sources was $400.5 billion in 2009, just shy of 3 percent of GDP. While the share of federal investment in R&D has declined, the private sector share has increased, which has maintained the ratio to GDP, but pulled activity toward the applied and development side of the continuum.



Source: National Science Foundation, *Science and Engineering Indicators, 2012*, Fig 04-05

National investment (all sources) in basic research was $76 billion in 2009 (0.53 percent of GDP), illustrating that resources are mostly focused on applied research or development. The federal government represented 53 percent of basic research investment, while industry funded 22 percent of the total. University-performed basic research was $40.6 billion (0.28 percent of GDP), and of this, the federal government funded $24.2 billion (0.17 percent of GDP).[1]

Industry approach to R&D

Research is an essential element of any knowledge-based company. In the semiconductor industry, we have learned from experience to manage through challenging times. Few sectors are as cyclical as ours with great highs and very difficult lows. Yet, the semiconductor industry consistently invests nearly the same percentage of sales in R&D, even as sales growth has fluctuated. In 2011, U.S. semiconductor companies invested $27 billion in R&D, or 18 percent of sales.

How TI invests in R&D

TI's R&D work runs the gamut from basic research, undertaken in collaboration with others in the industry, to more near-term applied research and development.

Nearer term research is embedded in business units throughout the company, enabling widespread access to innovative ideas that benefit TI customers, and allowing R&D staff to quickly gauge customer reaction to new ideas. TI also has additional R&D teams focused on broad areas of important technology, and around particularly promising applications.

In 2008, on the 50th anniversary of the invention of the integrated circuit, TI established Kilby Labs as a center of innovation at three sites within the company to inspire creative ideas for breakthrough technologies. The lab allows selected TI researchers to work full time on a high-risk, high-reward project for several months to a year. Engineers assigned to those Kilby projects then return to their business units. Areas being explored today include energy management, medical and health care, cloud computing (and related infrastructure), and safety and security.

The scope of projects is virtually unlimited within TI's fields of interest and expertise, and they have ranged from terahertz clock sources to micromachines. TI often engages with university professors on these efforts. Kilby Labs are also a magnet for top students from around the world, some of whom start as summer interns and then join TI after graduation. Student interns work with TI staff on projects, gain insight into how TI operates and at the same time further their graduate studies. Interns have come to work at Kilby Labs from universities near and far, including are the University of Texas, MIT, Texas A&M, Stanford, Columbia, Georgia Tech, Rensselaer, UC Berkeley, UCLA, the University of Illinois, the University of Wisconsin and Cambridge University.

Public-private partnerships: semiconductor industry examples

TI's basic research investments are almost always in collaboration with others to tackle fundamental technical challenges that no company or university can solve alone. The semiconductor industry has a wonderful tradition of supporting pre-competitive, collaborative research that dates back to the 1980s and which has evolved as the industry's needs and challenges have changed.

For example, the Semiconductor Research Corporation (SRC), founded in 1982, is a consortium of semiconductor companies that collaboratively funds pre-competitive university research in semiconductor technology and design. TI has been a member of SRC almost since its inception, contributing financial and human resources to maximize the impact and the value of the consortium.

Over the past five years, SRC has administered $215 million in industry funding for university research, supporting more than 1,500 students annually. These industry dollars are matched or leveraged by federal, state and other sources of funds. SRC's consortium model facilitates interaction between industry and government, allowing for co-investment in basic research with various federal agencies, including the National Science Foundation (NSF), National Institute of Standards and Technology (NIST), and Defense Advanced Research Projects Agency (DARPA). U.S. universities represent 97 percent of the investments that SRC makes.

Three SRC-administered programs – The Texas Analog Center of Excellence (TxACE), the Semiconductor Technology Advanced Research network (STARnet) and Nanoelectronics Research Initiative (NRI) – illustrate the pre-competitive research continuum, from nearest to longest term.

TxACE: Through SRC, TI led an effort to establish a collaboration center at the University of Texas-Dallas that focuses on research in analog and radio frequency technologies to address challenges in such areas as energy efficiency, health care, and public safety, which are uniquely reliant on analog technology. The center involves 29 universities, in Texas and outside the state. Total funding for the center is $31.8 million over six years, of which TI and the SRC are providing a combined $15.9 million, and the State of Texas, through the university system and Emerging Technology Fund is providing the remainder. This collaboration of academia, industry, and government is an excellent example of how regional innovation is created.

STARnet*:* Funded jointly by industry and the Defense Advanced Research Projects Agency (DARPA), the new Semiconductor Technology Advanced Research Network (STARnet) program will allocate a total of $194 million over the next five years to 39 universities across the country for leading-edge semiconductor research, concentrated along six thematic areas focused on extending and moving beyond the current CMOS technology (http://www.src.org/program/starnet/). STARnet is the successor to the Focus Center Research Program, also funded jointly by DARPA and industry in 1997–2012.

NRI*:* NRI looks even farther into the future, supporting discovery-oriented research that is focused on finding the next technology that will allow the industry to continue to increase performance and decrease cost. Initiated in 2005 by five semiconductor companies, NRI has been recognized by the President's Council of Advisors on Science and Technology and others as a model collaboration that leverages funding and expertise from industry, NSF, and NIST, as well as contributions from state and even local governments. Since the program's inception, industry has contributed $17 million, NSF $20 million, and NIST $12 million.

Why does investment in nanoelectronics research matter? Nanoelectronics is a game-changer for the industry and the country – a disruptive technology that could alter the dynamic of market leadership. The current chip technology, which has been used for four decades, is predicted to reach its scaling and power dissipation limits by 2020. Nanoelectronics holds the promise of a successor technology. The country that discovers this breakthrough research is likely to reap the related economic benefits. The U.S. federal government's research resources, specifically the NSF and NIST are critical to this effort. We appreciate the support that this committee has provided to this effort.

What is important to point out is that in all points along the R&D continuum, industry has skin in the game.

Global competition

Sustained funding of scientific research is required to maintain U.S. leadership and competitiveness. Numerous benchmarks used to measure our nation's innovation efforts, such as the numbers of scientific and engineering degrees awarded, scientific papers and patents produced, and total research investments, indicate that other regions and nations, particularly China and the other rapidly developing economies of Asia, are vigorously investing in science and technology in hopes that they can eventually surpass the United States in key scientific fields.

The United States was once the leader in research intensity, or R&D as a percentage of GDP; it now ranks 8th according to the OECD. U.S. share of global R&D spending is slipping, from 39 percent in 1999 to 34.4 percent in 2010. While U.S. R&D spending has risen on average 3.2 percent, other countries are accelerating their investment – South Korea at 8 percent and China at 20 percent.[2]

For my own industry – which remains the global leader and has on average been the top U.S. export over the last decade – this trend is disturbing. Although the industry has its roots in American innovation, our leadership cannot be taken for granted. Other countries want to attract this industry and many have specifically identified semiconductors in national development plans, establishing aggressive incentives to encourage semiconductor design, manufacturing and R&D. They see the benefits that result from a robust chip industry in terms of both economic activity as well as increased innovation. They are building talent, pouring resources into R&D, and in some cases trying to develop national champions with policies that favor domestic companies and create unique technical standards to force technology transfer.

A quick read of China's 12th five-year plan identifies seven emerging industries in which it hopes to become world-class competitors, including energy-efficiency and environmental protection, next generation information technology, bio-technology, advanced equipment manufacturing, new energy, new materials and new-energy vehicles. All are very innovation-driven, R&D intensive sectors. And China is making the investments. This is a challenge we need to address.

R&D incentives have become a highly popular way for countries to attract and develop their research base. Most of these are tax based. The United States once had the most competitive R&D tax credit. But according to the Information Technology Innovation Foundation, we now rank 24th of 42 countries, and because our credit is temporary it undercuts the very incentive it is supposed to provide. We welcomed the recent extension of the R&D tax credit, yet it is very difficult for companies to plan, or even prepare financial reports, when it is continually renewed retroactively or at the eleventh hour.

In addition to the R&D incentives, all our competitor countries have lower overall corporate tax rates, and many offer special incentives to specific industries such as tax holidays or reduced tax rates for semiconductor companies. A combination of these incentives can in some cases allow a company to operate up to 10 years virtually tax-free.[3]

Breakthrough technologies: semiconductors

History

I want to reiterate the game-changing implications of research by looking a bit to the past but also projecting out to the future. When Jack Kilby invented the integrated circuit at TI, NASA and the Defense Department were some of the first supporters. Federal funding was critical to development of semiconductor manufacturing technologies in the 1960s and 1970s.

The invention of the integrated circuit has propelled space travel, enhanced national security, revolutionized computing and communications, created safer cars and energy-efficient appliances, and improved health care technology. Today, semiconductors represent a $300 billion worldwide market, enable the more than $1 trillion global electronics market, and drive productivity in every sector of the economy. The industry has delivered a 10-fold drop in cost every six years. Investment in R&D is what makes this possible.

An example of a TI product that can trace its roots to federal research is Digital Light Processing (DLP®) technology, which is a digital mirror device. DLP® has its origins in DARPA projects from the 1970s to improve aircraft cockpit displays. The first commercial use TI found for the technology was for airline ticket printing. In 1989, DARPA funded a program to spur development of high-definition TV industry, which resulted in TI developing the first prototype digital mirror device. Now DLP® is an amazing imaging technology that uses millions of tiny, rapidly-moving mirrors moving thousands of times per second to generate up to 35 trillion colors. DLP® is used in nearly half of the world's projectors, including the handheld Pico, 3D television and movies, and revolutionary medical imaging. TI worked with the University of Texas-Arlington on some exciting research resulting in medical technology that uses DLP® for hyperspectral imaging, which uses electromagnetic spectrum bands to image beyond what the human eye can see, and has applications for non-invasive diagnoses. DLP® applications are being developed for 3D biometrics and there are numerous other projects underway. For TI, DLP® now generates about 6 percent of our revenue and supports hundreds of employees, most in the United States. Perhaps even more importantly, it also supports over 300 companies that are using our technology to create new applications for medical, automotive, and industrial sectors, illustrating that as technology becomes pervasive, it strengthens the broader economy as a byproduct.

Looking ahead

But that's just the beginning. What semiconductors made possible for the information technology industry will now revolutionize health care, security, energy, and transportation.

Bioengineering, at the intersection of medicine and engineering, is an incredibly exciting area. Research has helped develop retinal implants that will allow the blind to see, bionic prostheses, and wireless body sensor patient monitoring.

Other research-based technologies on the horizon include 3D biometrics, video analytics, perpetual devices (powered by ambient light, heat, or vibration), intelligent driverless cars, and wearable electronic devices (clothing, fingertips, and glasses). Emerging infrastructure and applications such as smart grid/energy management, cloud computing, data analytics, and the Internet of Things are driving new innovations. The possibilities are limitless. And research remains at the heart of making it all work.

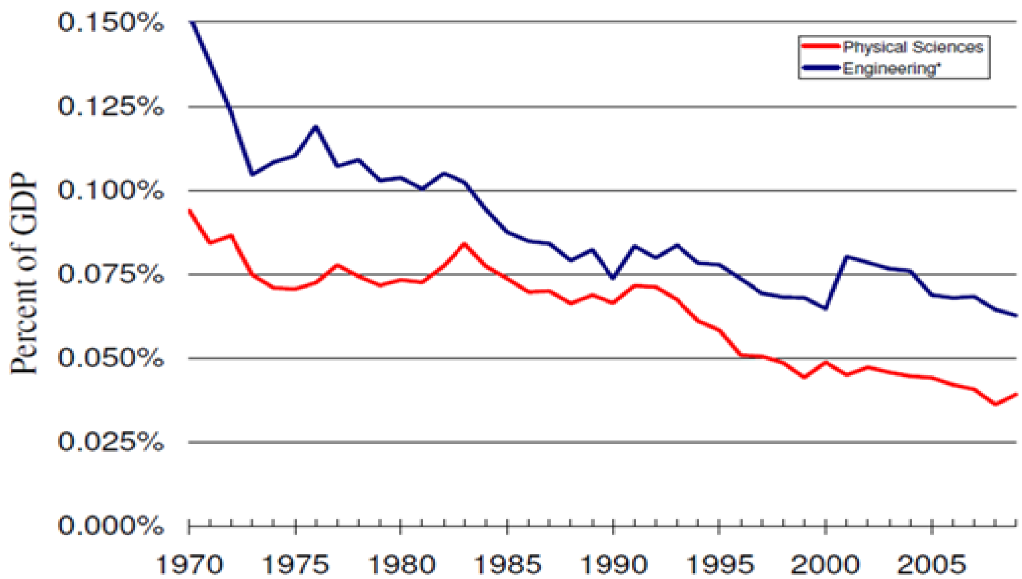
Policy Implications

Prioritizing research investment

The physical sciences and engineering are integral disciplines to the semiconductor industry and many others. Federal investment in these fields has declined as a percentage of GDP over the last four decades.

The key agencies funding physical science and engineering research are the National Science Foundation (NSF), National Institute of Standards and Technology (NIST), Department of Defense, Department of Energy Office of Science, and National Aeronautics and Space Administration (NASA).

Federal Funding of Research in Physical Sciences and Engineering



Source: Task Force on American Innovation

As the continuing resolution expires in March, I urge you to provide predictable and sustained funding for scientific research at these key agencies. Boom and bust funding cycles for scientific research hamper scientific progress and discourage students from pursuing scientific and technical careers that are critical to maintaining U.S. scientific leadership. Worse yet, those doing research here in the United States will increasingly consider lucrative offers to continue their research overseas, where the funding stream is more constant and dependable. When research moves out of the United States, the high skilled talent, the intellectual property and possible spinoff companies and corresponding jobs all leave with them.

Building and retaining talent

Research funding is one of the best tools we have to encourage graduate students in STEM fields. The federal investment in scientific research is essential to producing the next generation of scientists and engineers. Thousands of graduate students and post-doctorates, as well as undergraduates, obtain their most important laboratory experience in projects funded by federal research grants. The American system of combining research with training of young scientists and engineers has been enormously successful, and it would be impossible without federal funding.

In the case of public-private partnerships, these graduate students have excellent opportunities to interact with both academia and industry, paving the way for transition to either sector. Through its history, SRC has supported over 7,000 students as part of its unique collaborative research model. Of the SRC-supported students, most graduates have joined sponsoring companies or university faculties, or have continued on to pursue a higher degree. The opportunities graduate students are provided through research funding offer invaluable training for the future workforce of innovative industries and technical drivers of start-up companies.

A major regulatory challenge to research is the U.S. immigration system. Foreign nationals earn 55 percent of the masters' degrees and 63 percent of the PhDs in electrical engineering from our own U.S. universities. Yet these individuals face waits for permanent resident status (green card) lasting several years up to a decade, keeping professional and personal lives in limbo. We need to fix the high skilled immigration system to enable these highly educated professionals to remain in the United States. We are grateful for the leadership that you, Mr. Chairman, and Congresswoman Lofgren in particular have provided in this area. We encourage the Congress to address immigration reform this year. We are pleased that so many bipartisan discussions and initiatives are being developed on this front.

STEM education

Business and government must work together to build the pipeline of STEM students through initiatives that improve math and science proficiency, enhance teaching effectiveness, and ensure accountability. There is a skills gap in this country – for every unemployed person in the United States, there are two STEM job postings. The gap will only widen if we don't engage now to address STEM education at the elementary and high school levels. In 2011, only 45 percent of U.S. high school graduates were ready for college work in math and only 30 percent were ready in science. We also need to engage underrepresented groups in STEM – women, African Americans, and Hispanics. In particular, I'd like to recognize Ranking Member Johnson for her work over the years to address this issue. Creating policies and practices that foster STEM will eventually bring greater equilibrium between job seekers and job opportunities, and in the process strengthen U.S. competitiveness.

TI supports a number of programs designed to encourage student interest and achievement in STEM fields. In addition, TI actively promotes educational excellence with federal, state, and local governments. TI is an active member of Change the Equation, a U.S. private-sector organization of more than 100 chief executive officers focused on improving math and science education by scaling proven practices.

Tax policy

TI supports the efforts to enact comprehensive tax reform to make the United States more globally competitive. Corporate reform should fully contemplate the global nature of business. The worldwide marketplace is complex and highly competitive. We want to be sure that U.S. companies can compete effectively and that the United States becomes a highly attractive location in which to invest. Specifically, our industry seeks to align the U.S. tax system with those our global competitors enjoy by reducing the corporate tax rate, adopting a market-based tax system, and enacting permanent, robust incentives for research and innovation competitive with other countries.

Conclusion

As political leaders, you are facing some tough budget decisions in a challenging economic environment. I urge you to approach this challenge in a thoughtful, strategic way, allocating scarce funds in a manner that gives us the best chance to create economic growth and security both now and in the future. The semiconductor industry may be a useful example to demonstrate how prioritizing investment in research and establishing collaborations that leverage federal participation are an effective and workable model of engagement. Good times or bad, you must manage for the future. Innovation is the pathway there.

Federal funding of scientific research fuels the new ideas and technologies on which our economy, our health, and our national security depend. Predictable and sustained investments in scientific research funding is essential to our efforts to address many of the fundamental issues our society faces, such as energy, national security, and the continuing search for new life-saving medical technologies, vaccines and cures for diseases.

If we want the United States to remain the leader in cutting-edge technologies and knowledge-based industries, both government and industry must support science and engineering research. Investing in research means investing in our universities, in great ideas, and in talented people. It means investing in America.

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[1] *Science and Engineering Indicators*, National Science Foundation, 2012. GDP percentages calculated.

[2] *Rising to the Challenge: U.S. Innovation Policy for Global Economy*, National Academies Press, 2012.

[3] *Maintaining America's Competitive Edge*, Dewey and LeBoeuf study for the Semiconductor Industry Association, March 2009.