Written Testimony of
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Hearing on
"Five Years of the America COMPETES Act: Progress, Challenges, and Next Steps"

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Chairman, Ranking Member, and Members of the Committee, my name is Peter Lee, and I am a Corporate Vice President at Microsoft. Thank you for the opportunity to share perspectives on research, education, and the America COMPETES Act. I appreciate the time and attention the Committee has devoted to this topic, and I commend you for advancing the dialogue on innovation and competitiveness, including in information technology.

Microsoft deeply believes that investment in research and education lay the groundwork for advances that benefit society and enhance the competitiveness of U.S. companies and individuals. In my testimony, I will:

- describe the profoundly productive interrelationships between industry, academia, and government in the field of information technology;
- provide information and examples from our experiences and activities at Microsoft;
- mention some achievements that have occurred under the America COMPETES Act; and
- identify opportunities in computing research and education for the Committee to consider going forward.

My testimony today is informed by my experiences in academia, government, and industry. In the first area, I spent 22 years as a professor at Carnegie Mellon University, including serving as the Head of the Computer Science Department and as the Vice Provost for Research. Between Carnegie Mellon and Microsoft, I served in the Department of Defense at DARPA, the Defense Advanced Research Projects Agency. There, I founded and directed a technology office that supported research and developed innovations designed to keep our military at the leading edge in computing and related areas. Now, I hold the title of Corporate Vice President, Microsoft Research, where I am responsible for managing Microsoft Research Redmond, a laboratory of over 300 researchers, engineers, and support personnel dedicated to advancing the state of the art in computing and creating new technologies for Microsoft's products and services.

We're In This Together

My experiences in industry, academia, and government have given me a range of perspectives on the challenges and opportunities we face in sustaining a strong innovation ecosystem that not only is first to create new knowledge, but also is effective in deploying that knowledge to

improve our society and security and maintain American competitiveness in the global economy. From the inside of some of our nation's best research organizations, I have seen first-hand how the rich interplay between industry, academia, and government produces a continuous stream of technological and business innovations. In a nutshell, our nation has been remarkably effective in supporting a productive, interconnected ecosystem of people, ideas, projects, and resources that today drive American competitiveness. The COMPETES Act is a prime example of this support.

I will focus specifically on the field I know best, which is information technology (IT). The commercial IT industry is a well-known and well-appreciated success story of American innovation and leadership. American ingenuity has turned advances in IT into an incredible driver for global competitiveness and economic growth. Today, IT contributes about 5% to overall U.S. GDP, according to the Bureau of Economic Analysis. Yet the success was not solely the outcome of visionary and very hard-working people at companies across the U.S., such as Microsoft. Instead, it is the result of a tightly interconnected ecosystem of people, ideas, projects, and resources from government, academia, and industry.

The nature of this complex partnership is illustrated in the recently released report *Continuing Innovation in Information Technology*.[1] (I chaired the National Research Council committee that produced this study.) The centerpiece of that report is a diagram, referred to as the "tire tracks." (See Appendix A.) This diagram illustrates how fundamental research in IT, conducted in industry and universities over decades, and supported by Federal agencies, has led to the introduction of entirely new product categories that ultimately became the basis of new billion-dollar industries, including broadband and mobile technologies; microprocessors; personal computing; the Internet and the Web; cloud computing; enterprise systems; entertainment technologies; and robotics. In all of these cases and more, there is a complex interweaving of fundamental research and focused development, with innovations in academia driving breakthroughs in industry and vice versa; with ideas and technologies transitioning among fields and applications, creating opportunities in both new research and new products and markets.

The three sectors of academia, government, and industry play complementary roles in ensuring the health of the innovation ecosystem. In particular, the study notes that "the government role has coevolved with the development of IT industries: its programs and investments have focused on capabilities not ready for commercialization and on the new needs that emerged as commercial capabilities grew." This evolving role of Federal agencies, and the research communities they support and nurture, is a critical complement to the activities of companies both large and small. Large companies, on the whole, are driven to invest more in product and process development, with clear connections to existing products and markets and planned rewards that can be demonstrated to shareholders in the near term. Start-up companies, while more open to potential new areas and opportunities, are focused on the implementations that make real the discoveries of past research, not on conducting new investigations.

Without research agencies and universities to focus on the ever-shifting frontiers of multiple computing sub-disciplines, to explore connections across disciplines and products, and to expose

[1] *Continuing Innovation in Information Technology*; Committee on Depicting Innovation in Information Technology; Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences; National Research Council. http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_045476.

each generation of students to an array of future possibilities, companies will not have the reservoir of ideas and talent to maintain the U.S. lead in today's IT sector and build the next set of multi-billion dollar job-creating industries.

The U.S. has demonstrated time and again that the three components of the IT innovation ecosystem are each strong and the vital connections among them are robust. Yet this situation is not a guaranteed right. It is a result of sustained investment and a nurturing environment. Other nations have looked at the U.S. successes and are applying the lessons they have learned about how to invest in research, to nurture a culture of original discoveries at universities, and to deploy a legal and regulatory framework to encourage innovation. India and China both have made significant progress and are likely to benefit from having sizable internal markets for IT products. Other nations, such as Ireland, Israel, Korea, Taiwan, Japan, and some Scandinavian countries, are also developing strength in specific areas within various IT sectors.[2]

Microsoft Research

Microsoft is a direct beneficiary of, and wholly committed to, its role in the innovation ecosystem described above. This requires significant investments by us in various elements of this ecosystem. Across the company, more than $9 billion a year is directed toward research and development (R&D), with the vast majority of those funds supporting development activities focused on specific products. A critical element, although small in dollar terms, of our overall R&D investment is in more fundamental explorations at Microsoft Research (MSR). Founded in 1991, MSR is now the largest and highest quality industrial computing research organization in the world, with over 800 Ph.D.s working in more than 55 research areas. MSR is dedicated to advancing the state of the art in computing, often in collaboration with academic researchers and government agencies, and to creating new technologies for Microsoft's products and services. This organization and these people allow Microsoft to respond more rapidly to change and provide a reservoir of technology, expertise and people that can be quickly brought to bear to respond to and create new technologies, new competitors, and new business models.

While MSR activities are distinct from the short-term development activities conducted at Microsoft and other companies, distinctions such as "basic" versus "applied" don't really apply to computing research. In fact, computing research is a unique and intoxicating blend of invention, discovery, and engineering. MSR researchers collaborate with leading academic, government and industry colleagues and often move in and out of universities and Microsoft business groups as the type of activities they are engaged in shift in focus.

I like to say that within MSR we can see the incredible range of possibilities in computing research come alive. A recent example is Microsoft's Kinect, which allows you to control games by using your body and voice. The real achievement here is the creation of a system which recognizes people and their voices in a variety of environments, tracks and responds to their body motions in real time, and can be produced in bulk. The technology builds on decades of blue-sky and disruptive research, conducted both in academia and in MSR, in a range of areas

[2] *Continuing Innovation in Information Technology*, http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_045476, page 11.

including machine learning, image processing, audio processing, and natural language processing.

The impact of Kinect is just one example of the connections and synergies between industry and academia that are discussed in the *Continuing Innovation in Information Technology* and illustrates how information technology shifts and evolves from research to products back to research. By providing a flexible and affordable system by which visual and voice feeds can be processed and used by a computer, Kinect is already transforming a variety of academic research projects and applications in robotics, human-computer interaction, online education, and more. In addition, the advances originally targeted at the gaming and entertainment business are having multiplier effects outside the IT sector as the technology is investigated for deployment in retail (virtual car tours)[3] and for healthcare applications (such as autism or post-stroke physical therapy).[4]

The Demand for STEM Knowledge

Microsoft and MSR actively rely on a vibrant and effective education system within the national research environment to produce a pipeline of diverse and highly qualified graduates. MSR supports a variety of activities to strengthen this pipeline, including fellowships for students and early career professors and programs to increase the recruitment and retention of girls and women in computing. A key element of our deep connection with the community is our annual internship program. We bring over 1,800 student interns to Redmond each year, with over 300 in Microsoft Research. The MSR interns participate in cutting-edge research and also learn about how advances fit into the context of a company that must continuously provide innovative products to thrive. This experience helps prepare students for a variety of career paths – as professors, as entrepreneurs, as industry researchers, and some even as Microsoft employees.

A main reason that MSR, and Microsoft as a whole, devote significant attention to our internship programs is that the success of Microsoft is strongly dependent on the talent of our employees. We aggressively seek out talented people who will help build our company into one that is successful in improving our current products and creating new ones as we participate in the rapid change that characterizes our innovation-based economy. Yet in August 2012, Microsoft had more than 3,400 unfilled research and engineering positions in the United States, a 34 percent increase in our number of unfilled positions compared to a year ago. And predictions suggest that this situation could get worse. The Bureau of Labor Statistics estimates that between 2010 and 2020, there will be at least 1.2 million job openings in computing professions that require at least a bachelor's degree (on average 120,000 per year) and that in 2020 half of the over 9 million

[3] More information about how the Kinect is being used in other commercial sectors is available at http://www.microsoft.com/en-us/kinectforwindows/.

[4] More information about how the Kinect is being used in healthcare, education, the arts, and other applications is available at http://www.xbox.com/en-US/Kinect/Kinect-Effect.

STEM jobs will be in computing.[5] Yet in 2010, only about 60,000 bachelor's, master's, and Ph.D. degrees were awarded in computer science[6] – far less than the predicted demand.

As information technology permeates many aspects of our day-to-day lives and becomes a critical element of sectors from manufacturing to healthcare, from retail to education, other companies too will be searching for the people with the core knowledge and creativity to reinvent how we do business and keep American companies at the forefront of the global economy. Just in the area of skills related to the explosion of "big data" in multiple industry sectors, the McKinsey Global Institute predicts a shortfall of 140,000 to 190,000 people with deep analytic skills (e.g. in statistics and machine learning) and 1.5 million managers and analysts with the skills to interpret and make decisions based on the data analysis.[7]

Microsoft recognizes that many U.S. employers are searching for people with the skills and talent we need to be globally competitive. On September 27, Brad Smith, Executive Vice President and General Counsel at Microsoft, will speak in Washington, DC at the Brookings Institution on this issue and the policy changes necessary to foster an education system that provides opportunities for students to access the type and levels of education required to secure jobs in innovation-based industries.[8] We look forward to continuing the conversation on STEM education and policy with the Members of this Committee and the larger government, industry, and academic communities that all have roles to play in this important area.

Five Years of the America COMPETES Act

Since the America COMPETES Act was passed in 2006 and reauthorized in 2010, the agencies covered under the Act have made important contributions to advancing our fundamental understanding of the world and training the next generation of scientists and engineers. In computing, there are several achievements of the past five years that would not have been possible without key contributions by the Federal government.

Research

Under America COMPETES, we have seen significant interagency collaboration on research targeted at major challenges and opportunities. Two recent examples are the initiatives in robotics and "big data." These both illustrate the interconnections between industry, academia, and government described above, as they are simultaneously areas for cutting-edge fundamental

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[5] This estimate is based on the Bureau of Labor Statistics' occupational employment and job openings data, projected for 2010-2020, http://www.bls.gov/emp/. Further analysis of the computing jobs predictions are available from the Association of Computing Machinery, http://cacm.acm.org/blogs/blog-cacm/147077-computer-science-jobs-and-education-presentation-slides/fulltext.

[6] From the Integrated Postsecondary Education Data System from the U.S. Department of Education's National Center for Education Statistics, available at https://webcaspar.nsf.gov.

[7] Report from McKinsey Global Institute, *Big data: The next frontier for innovation, competition, and productivity*, May 2011, by James Manyika, Michael Chui, Brad Brown, Jacques Bughin, Richard Dobbs, Charles Roxburgh, Angela Hung Byers. http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation.

[8] Brookings Institution Event on "Education and Immigration Reform: Reigniting American Competitiveness and Economic Opportunity" on September 27, 2012. See http://www.brookings.edu/events/2012/09/27-stem-education.

research on hard problems that will occur at universities and industry labs, and also the focus of development and deployment activities at large corporations and in the operations of government agencies.

The National Robotics Initiative was launched in June 2011. The focus is on "co-robotics" – enabling the development of robots that work with or beside people to extend or augment human capabilities, taking advantage of the different strengths of humans and robots. An important characteristic of the initiative is that it both supports core research in areas such as computer vision, language processing, and dexterous manipulation that will advance robotics capabilities across the board while also supporting research targeted at key robotics applications in areas such as health, manufacturing, agriculture, defense, and space exploration.

The federal Big Data Initiative was launched in March 2012. This initiative builds on many years of research at multiple agencies to improve the creation, management, analysis, fusion, visualization, understanding, and use of very large data sets. Advances in these areas will improve scientific research (e.g. on disease or the environment) and facilitate real-time decision making (e.g. in the defense and intelligence sectors or electricity grid management). Increasing the ability to generate and interpret big data is already having an impact in diverse sectors, from retailing to healthcare[9], and federal investment will create new capabilities with even broader benefits. At Microsoft, as well as our industry competitors, we are making big bets on Big Data. Already, today, nearly every product and service offered by Microsoft is improved or enabled by computing research advances in an area called machine learning, which pertains to the design of systems that become more effective with experience. Today, that "experience" is gained through the analysis of big data. Whether it is the analysis of large numbers of electronic health records to improve patient care for individuals, or the use of massive amounts of training data to improve how well Kinect can track a videogame player's movements, advances in big data provide a critical foundation for our products.

Another emerging example can be found in research on how large numbers of interconnected people and computers can be used together to solve hard problems. While I was at DARPA, I led an experiment to see if social networks could be used to rapidly mobilize very large numbers of people to conduct coordinated operations at global scale. The resulting "red balloon hunt" (officially called the 2009 DARPA Network Challenge) inspired millions of people around the globe to collaborate. This experience had a major impact on thinking within the Department of Defense. Another approach to this phenomenon can be seen in FoldIt, which was also supported while I was at DARPA. FoldIt is a crowdsourced computer game for protein folding and protein structure calculation, and last year it was used to solve an AIDS-related protein structure problem whose solution had eluded the scientific community for a decade. At Microsoft and other companies, some products and services, such as search engines, are improved as more people use them, a form of crowdsourcing. While we have embarked on early research into the potential of such online task markets, we rely on new government research programs, for example on "social computing," to build a coherent research community and pool of talented researchers to collaborate with and hire.

[9] The McKinsey Global Institute Big Data report referenced above analyzes the potential impact of big data on five domains, including manufacturing, retail, and public sector administration.

Education

A key attribute of the America COMPETES Act and its reauthorization is the recognition of the importance of every element of the system that contributes to science, technology, engineering, and mathematics (STEM) education in the U.S. From K-12 to undergraduate, from graduate education to post-doctoral studies and early career faculty, federal programs have an opportunity to improve the approaches taken in schools and universities to ensure rigorous and engaging courses are offered and students have the opportunity to experience and explore the STEM fields.

Two examples of recent programs that supported the goals of America COMPETES are Computing Education for the 21st Century (CE21)[10] and the Computing Innovation Fellows (CIFellows),[11] both out of the National Science Foundation.

The CE21 program focuses on generating knowledge and activities related to computing education with the goal of building a robust computing research community, a computationally competent 21st century workforce, and a computationally empowered citizenry. Examples of work underway in this program include development of resources to facilitate expansion of computer science teaching in high school, such as the design assessments and models of teacher professional development for new courses, including a new computer science AP course, research on the teaching and learning of computational competencies, and alliances to broaden participation in computing careers. CE21 is ongoing and continues to provide important contributions necessary to advance computing education in the U.S.

The CIFellows Program is a program that ran from 2009 to 2011 and was a targeted response to concerns that the economic climate in 2009 would force a large number of new Ph.D.s in computer science and related fields to delay or altogether abandon a research career in academia or industry. By providing post-doctoral fellowships, which historically had been less common in computing than other fields, and matching awardees to mentors, the CIFellows program provided interim employment and career development at a critical juncture where the research workforce pipeline was in danger of breaking down. It is still early to fully assess the impact of this program, but many of the CIFellows have now found permanent employment in research organizations (including at Microsoft Research) where they can contribute to the innovation opportunities outlined elsewhere in this testimony.

Looking Ahead

As a nation, we can be proud of the achievements that occurred under the past five years of America COMPETES, but there are still research questions to be answered and societal challenges in technology and education to be tackled. The activities of the past lay the groundwork that we can build on going forward. Below I provide several observations about the

[10] The National Science Foundation's Computing Education for the 21st Century (CE21) program is described at http://nsf.gov/funding/pgm_summ.jsp?pims_id=503582.
[11] Information about the Computing Innovation Fellows Project is available at http://cra.org/ccc/cifellows.

opportunities that exist for the Committee to consider as it begins reauthorization of the America COMPETES Act.

Invest in the future of research

The impact and results of research are often unknown when the research is started. The value and payoff of a sustained and healthy investment in research is often realized well after the initial work is done. Today, the U.S. is reaping the benefits in both our quality of life and in the global competitiveness of our companies that builds on past investments. According to estimates by the Bureau of Economic Analysis, the IT-intensive "information-communications-technology-producing" industries grew by 16.3 percent in 2010.[12] The strength of these industries are built on research in many areas over many years. One example is research on coding theory that eventually enabled modern cell phones and streaming video through the Internet.[13] Another is the research on distributed computing, including in software, storage, and networking, that provided the underpinning of today's rapidly-expanding cloud computing industry, in which the U.S. is the international leader.

Grand Challenges and Computing Research: To maintain American leadership in a world where information, knowledge, and people move rapidly around the globe, the U.S. must support research in all disciplines of science and engineering. Many of the grand challenges facing society require not a single breakthrough in a single area, but the contributions of researchers in multiple fields and the integration of new knowledge into complex systems. Computing is often a central element in tackling these grand challenges and improving healthcare, transportation, education, national security, energy independence, scientific discovery, and prosperity. Looking ahead, examples of the opportunities that exist include:

- Advances in big data and robotics targeted at refining and reimagining our transportation and energy systems to improve reliability, safety, and efficiency.
- Continued focus on designing IT systems for security and robustness in light of different levels of risk and threat posed by different applications and environments.
- Advances in networking and mobile computing to enable next-generation technology and policies around spectrum sharing[14] in order to provide the global connectivity among people, devices, sensors, and the cloud that will allow benefits in areas such as continuous health monitoring and smart buildings and cities, as well as expand access to information and technology throughout the world.
- Technical and social science research to underpin privacy technologies and policies.
- Integrating IT capabilities with educational knowledge to deploy personalized or just-in-time learning tools and systems that improve networks and information for teacher and schools.

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[12] *Continuing Innovation in Information Technology*, http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_045476, page 1.
[13] *Continuing Innovation in Information Technology*, http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_045476, page 11.
[14] The potential benefits of spectrum sharing and the associated policy and technical issues are described in *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*, President's Council of Advisors on Science and Technology, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

Cyberinfrastructure: New technologies from computing have always played a key role in enabling discoveries across multiple fields of science and engineering. Today, modern science increasingly relies on integrated information technologies and computation to create, collect, process, and analyze complex data. Federal agencies must continue to support research and deployment activities that facilitate effective use of cyberinfrastructure[15] in ways that recognize the changing scale and types of scientific information and the rise of the "fourth paradigm" of data-intensive science.[16]

Interagency Coordination and Existing Legislation: Information technology research and education is a critical element within the mission and activities of multiple Federal agencies, and the interagency Networking and Information Technology Research and Development (NITRD) program has for years facilitated the coordination of these activities. The President's Council of Advisors on Science and Technology (PCAST) report on *Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology*,[17] and the upcoming PCAST update of that report, clearly articulate the opportunities in NIT and recommendations for moving forward. Microsoft is supportive of the reauthorization of the NITRD program, whether as part of the COMPETES reauthorization or as stand-alone legislation.

Invest in the future of people

Technology, including information technology, is permeating society. Citizens of the 21st century will need core analytical and quantitative knowledge to manage every-day tools such as smartphones and programmable thermostats, to fill well-paying jobs in multiple technology-dependent industrial sectors, and to create the new technologies that fuel the innovation economy. The Federal agencies have key roles to play in ensuring that students today receive the education they need for society to thrive in the years ahead.

Computing Education: As discussed throughout this testimony, understanding, using, and creating information technology is key for people involved in research and education, in STEM jobs in industry and government, and in daily life. Agencies should support efforts to expand computing education, particularly at the K-12 level, and ways to increase exposure to computing education and research opportunities at the university level, for both computing majors and those in other disciplines.

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[15] The role of networking and IT infrastructure in research in other fields is discussed in *Designing a Digital Future: Federally Funded Research and Development Networking and Information Technology*, President's Council of Advisors on Science and Technology, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf.

[16] Further discussion of the impact of advanced computing capabilities on multiple fields of science is available in *The Fourth Paradigm: Data-Intensive Scientific Discovery*, http://research.microsoft.com/en-us/collaboration/fourthparadigm/default.aspx.

[17] *Designing a Digital Future: Federally Funded Research and Development Networking and Information Technology*, President's Council of Advisors on Science and Technology, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf.

At the K-12 level, good work has been done to date in universities on courses and professional development (as mentioned above) and advances have been made in some states and cities. Yet still only nine states allow computer science courses to count as part of the "core" curriculum that students can choose to pursue to graduate from secondary school.[18] More information about the opportunities and policy challenges is available from the Computing in the Core coalition (http://www.computinginthecore.org/), of which Microsoft is a founding member.

At the higher education level, it is important that the system have the capacity to expand to serve a hopefully growing number of people wishing to study computing. Also important is that the content and approaches used in college computing courses reflect what is being learned about engaging and effective learning and up-to-date content in rapidly-changing areas such as cybersecurity.

In addition to activities that support these goals specifically, it is important that general Federal "STEM" programs—whether for teacher development and support, pedagogy research, undergraduate education, or other areas—recognize that computer science is included in their purview and clearly enable its inclusion through their solicitations, outreach, and review criteria. While the importance of including computer science in STEM has been widely recognized for several years, accomplishing this may require coordinated action by government agencies.

Education Across Disciplines and Integrated with Research: The pace of change and discovery in science and engineering is increasing, as is the amount of work involving researchers from multiple disciplines. Universities are well-positioned to respond to these trends, and Federal agencies should continue to support and drive universities to enable students to engage in interdisciplinary courses of study and also to develop opportunities and resources for students to access courses and knowledge from outside their primary area of study. Also it is important that we preserve and build on the integration of research and education that is possible within the U.S. research university system for undergraduates and graduate students. This exposes students to the cutting edge of rapidly changing fields and, through those students and their post-graduation employment in industry and elsewhere, improves the transfer of knowledge from academia.

Diversity: The demographics of the nation are changing. Society benefits when people have access to multiple fields and career choices. Women and certain minorities have historically been underrepresented in many science and engineering fields, including computing. A number of efforts are underway to shift this situation, and we all must continue to strive to improve diversity in science and engineering.

Summary

- Past investment in computing research has spawned multiple new billion-dollar IT industries that have significant positive impact on the U.S. economy.

[18] Eight states count computer science as a mathematics credit – Missouri, New York, North Carolina, Oklahoma, Oregon, Rhode Island, Texas, and Virginia – and one (Georgia) counts it as a science credit. CSTA, ACM (2010). *Running On Empty: The Failure to Teach K–12 Computer Science in the Digital Age*. Available at http://www.acm.org/runningonempty/.

- Advances in IT are also enabling innovation in multiple sectors (such as manufacturing, healthcare, energy, education, and retailing).
- Innovation in IT results from an interconnected ecosystem in which government, universities, and industry each play a critical role.
- Federal investment in research is a critical component of tacking national challenges in transportation, health, energy, education, and other areas. This will require support for both multidisciplinary research and strong investments in advancing the core of all research areas, especially computing. It will also require support for the development and deployment of cyberinfrastructure.
- People will need STEM skills, especially computing knowledge, to be citizens, employees, and innovators in the 21st century technology-infused world.
- Strengthening the pipeline of STEM education, including computer science education.

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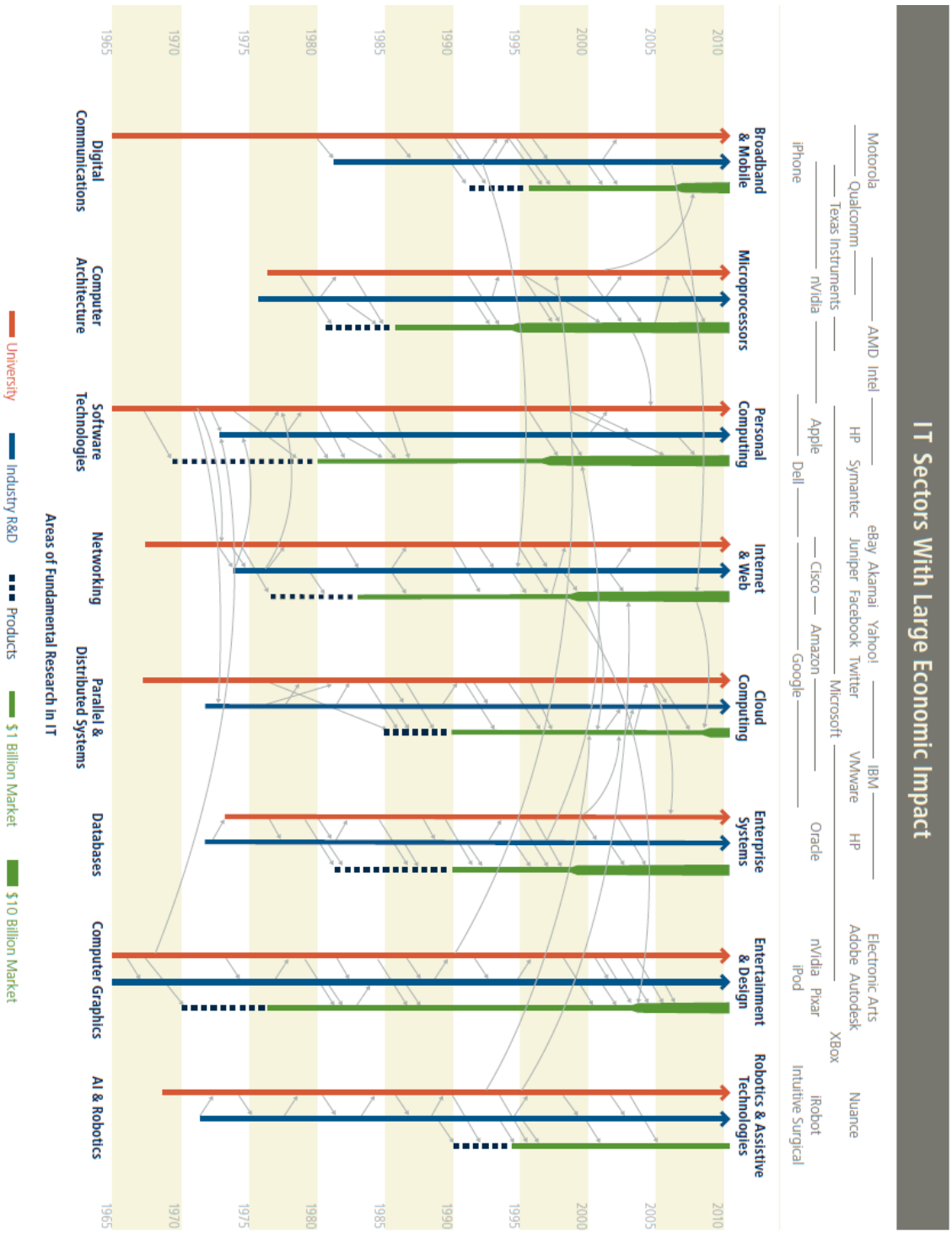
In conclusion, I believe that Federal agencies, companies, and universities all have major responsibilities in the interrelated system by which curiosity becomes discovery, and knowledge is deployed for the sake of the nation's competitiveness and society's well-being. The reauthorization of the America COMPETES Act is an important step toward providing Federal research agencies with the resources and guidance they need to contribute to our innovation ecosystem.

Finally, let me thank you for this committee's longstanding support for scientific discovery and innovation. I would be pleased to answer any questions you might have.

Appendix A: The Tiretracks Diagram



This is Figure 1 from National Research Council, *Continuing Innovation in Information Technology*, National Academies Press, Washington, DC, 2012. Full report is available at http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_045476.

Witness Biography

PETER LEE
MICROSOFT

Dr. Peter Lee holds the title of Corporate Vice President, Microsoft Research. In this position he is responsible for managing Microsoft Research Redmond, a laboratory of over 300 researchers, engineers, and support personnel dedicated to advancing the state of the art in computing and creating new technologies for Microsoft's products and services. Prior to joining Microsoft, Dr. Lee was a professor at Carnegie Mellon University. A devoted teacher and a researcher with over 100 research publications, distinguished lectures, and keynote addresses, he served as the Head of CMU's Computer Science Department and before that had a brief stint as the university's Vice Provost for Research. Peter Lee also served in the Department of Defense at DARPA, the Defense Advanced Research Projects Agency. There, he founded and directed a major technology office that supported research in computing and related areas in the social and physical sciences.

Peter Lee has shown executive-level leadership in world-class research organizations spanning academia, government, and industry. He is a Fellow of the Association for Computing Machinery and serves the research community at the national level, including policy contributions to the President's Council of Advisors on Science and Technology, membership on the National Research Council's Computer Science and Telecommunications Board, former chairmanship of the Computing Research Association, and testimony before the U.S. House Science and Technology Committee.