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Testimony of

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Good morning Chairman Thune, Ranking Member Nelson, and members of the Committee; thank you for inviting me to share the views of the Information Technology and Innovation Foundation (ITIF) on the reauthorization of the America Competes Act. The Information Technology and Innovation Foundation is a non-partisan think tank whose mission is to formulate and promote public policies to advance technological innovation and productivity internationally, in Washington, and in the states. Recognizing the vital role of technology in ensuring prosperity, ITIF focuses on innovation, productivity, and digital economy issues. ITIF has long been involved in the policy areas Competes addresses, including science policy, tech transfer, and STEM (science, technology, engineering, and math) education. I very much appreciate the opportunity to comment on these issues today. I also want to mention that I appreciate having been invited by the Committee to a prior roundtable on Competes Reauthorization and want to commend the Committee for having such an open and inclusive process for receiving input on the bill from a wide range of stakeholders.

Why America Needs Competes Act Reauthorization

Reauthorization of Competes is crucial to the well-functioning of the U.S. innovation system. It is no longer enough to simply fund scientific and engineering research and hope it gets translated into commercial results with the U.S. economy. This is true for two key reasons. First, for many decades after the Soviets launched Sputnik in 1957 the U.S. government invested considerable sums into research and development (R&D). And if some of that research "sat on shelf" or lay largely unread in a journal we could rest easy in knowing that at least some of it got into new technology-enabled products, processes, and services. But because of budget limitations we no longer have that luxury. In fact, according to the National Science Foundation (NSF), federal funding for R&D in 2016 as a share of GDP will be the lowest it has been since the Russians launched Sputnik, almost 60 years ago. To restore federal R&D to GDP ratio to levels averaged in the 1980s, the federal government would have to invest $65 billion more per year. These lower funding levels mean we need much more efficiency in how we transfer discovery to commercialization within the U.S. economy if we are to avoid a reduction in the pace of innovation.

Second, for many decades after WWII the U.S. innovation system was unique in that few other nations had a well-established science and engineering system that could generate, absorb and commercialize discoveries. Moreover, a less interconnected globe limited internationally the geographic spillover of U.S. discoveries. This meant that much of the benefits of the scientific and engineering research the federal government funded stayed in the United States to the benefit of our economy as firms used the discoveries to build globally competitive positions. But as we point out in our book *Innovation Economics: The Race for Global Innovation Advantage,* over the last two decades many nations have put in place much more sophisticated innovation systems (e.g., funding research universities, supporting STEM education, crafting R&D tax incentives) to the point now where they are more easily able to take advantage of the knowledge discoveries stemming from U.S. investment in R&D. Now, if the United States does not commercialize its own R&D, a competitor nation likely will.

In short, given the decline in R&D funding and the dramatic increase in technological competencies of our economic competitors, we can no longer simply hope that some of the R&D funding ends up actually being used. This is why the Competes reauthorization is so important because it focuses on improving the efficiency of the process by which federally funded knowledge creation leads to actual innovation and U.S. jobs.

At one level this is good news. Improving the efficiency of the scientific and engineering research system can provide significant benefits at a lower budgetary impact than increasing funding without improving the efficiency. But continuing to underfund research while also not improving the efficiency of the system with the kinds of measures in Competes is a recipe for underperformance. And to be clear doing both is ideal: more federal funding for R&D and a better commercialization and tech transfer system.

Why Federal R&D Policy Needs to Go Beyond Simply Funding Research

Before discussing particular provisions that I believe are needed, it's important to briefly discuss why these kinds of provisions are needed. Won't the knowledge created by federal R&D funding naturally get commercialized? Won't the institutions involved, especially universities and federal labs, naturally want to transfer technology? Why should federal policy and funds be focused on this? The short answer is that the process of innovation from discovery to application is usually not an easy one, despite what Vannevar Bush suggested when he penned *Science: The Endless Frontier* 70 years ago. As more scholarship about the nature of innovation has been developed it has become clear that the process of innovation is much more complicated and subject to many failures and problems that require a more strategic role for government along the entire innovation lifecycle.

Yet, the current federal system of funding R&D still is based on a "linear model" of research that simply assumes that basic research will get transferred into new products and services. For example, only 2 percent of the NSF budget goes to programs focused on the development and commercialization of knowledge through industry-university partnerships. Given institutional inertia, coordination and communication challenges, and lack of funding for proof of concept research, overcoming the "valley of death" between basic research and its real world application is often the most difficult part of the innovation process. If this jump is not able to be made, the benefits of the money spent on knowledge discovery will be more limited.

The roadblocks and challenges are many. The culture and reward system in many universities and labs is oriented to research, not application or transfer. This is reflected by the very dramatic difference in performance of U.S. universities when it comes to technology commercialization, whether it's enabling start-up companies or transferring technology to existing companies. The seminal report *Innovation 2.0: Reinventing University Roles in the Knowledge Economy* finds that while the best universities and colleges in America are world class when it comes to transferring knowledge, many are not and need to learn from and copy the best practices of the leaders. To be sure, compared to even five years ago, America's universities and colleges appear to be doing a better job of technology commercialization, but there is still a wide variance between them in terms of the focus on and effectiveness of commercialization. One measure of this is the share at which industry funds university academic research. Of the top 30 U.S. research universities, the percentage ranges from 17.8 percent at Duke and 13.6 at MIT to just 0.9 percent at Brown and 2.2 percent at Johns Hopkins. There is also significant variation by state, with the U.S. average at 5.4 percent, but North Carolina at 9.8 percent, Kansas at 7.8 percent, New York and Ohio at 7.7 percent, but Michigan at just 3.1 percent. Moreover, the share has been falling, from 7.4 percent in 1999 to 5.4 percent now. We need more universities and colleges to be closer to national best practices. This means, for example, more universities should recognize patenting and commercialization success as part of tenure consideration, something which is currently the case at less than one-quarter of America's top 200 universities. More universities should also

allow faculty members to suspend their tenure so that they may pursue commercialization opportunities. More universities should also define an entrepreneurial leave policy for undergraduate and graduate students in which students could retain full-time student status for several years while launching their own company.

Even if institutions are focused on transferring technology, there are multiple hurdles, some of them from federal regulation, others stemming from market failures like the high costs of information search. Moreover, there is significant complexity of modern technology-based industry structures from the fact that the scope of technology systems and hence the number of supplier industries has grown as technological complexity has expanded, creating major information and coordination market failures that lead to poorly functioning innovation systems. On top of that there is a second "valley of death" in the process of scaling up prototypes where promising discoveries can flounder, never making it to final production. In part this is because many companies—in part because of pressures from capital markets—have become more risk adverse, preferring, in the terms of Harvard's Clay Christensen, sustaining, rather than disruptive, innovation.

Congress has a long tradition of legislation focused not just on funding R&D but on improving the functioning of the U.S. R&D system. In 1980 it passed the Stevenson-Wydler Technology Innovation Act and the Bayh Dole Act. The latter legislation permitted inventors receiving federal funds for research to own the invention rights. The former legislation stated that "technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States." In 1982 the Reagan administration supported the establishment of the Small Business Innovation Research Program (which required federal agencies to allocate a small share of their R&D budgets to small business research projects). Congress also passed a number of important laws, including the Federal Technology Transfer Act of 1986, National Defense Authorization Act for FY 1991, the Technology Transfer Improvements and Advancement Act, and the Technology Transfer Commercialization Act. Perhaps most important was the Omnibus Trade and Competitiveness Act of 1988. Among other things, the Act created the Technology Administration in the Department of Commerce, reorganized the National Bureau of Standards into the National Institute of Standards and Technology, and created a number of programs to help industry with innovation, including the Malcolm Baldridge Quality Award and the Boehlert Rockefeller State Technology Extension Program.

Recommendations for Competes Reauthorization

Thera are many components of Competes that will have important beneficial impacts on the U.S. innovation system. Let me suggest a few areas that I believe are especially important.

One focus of Competes is rightly on reducing the barriers and improving the incentives for commercialization. In this respect, small changes and modest amounts of funding can have an outsized impact. For example, ITIF partnered with the Center for American Progress and the Heritage Foundation to issue a report *Turning the Page: Reimaging the National labs in the 21st Century Innovation Economy*. The report included a number of low- or no-cost recommendations that would give the labs more flexibility and more incentives to see that more of their path-breaking research gets transferred to and used by companies in the United States. These included steps such as allowing labs to use flexible pricing for user facilities and special capabilities, adding weight to technology transfer in the expanded Performance Evaluation Management Plan, and removing top-down accounting rules to give labs more flexibility.

Similarly, there are a number of steps that can be taken to better link American universities with industry. For example, it is striking that the United States lags so many nations in terms of the linkages between universities and industry. In fact, as a share of GDP among the 39 OECD nations, the United States ranks just 27th in industry funding of university R&D, as ITIF writes in its report *University Research Funding—Still Lagging and Showing No Improvement*.

One way to remedy this would be to provide support and incentives for universities to update the curriculum and approach of university engineering programs to better prepare engineers for careers in innovation and advanced manufacturing and better link university research to industry needs. Senators Coons, Graham, Ayotte, Gillibrand, Baldwin, Kirk, and Franken have partnered to introduce legislation, endorsed by 26 House co-sponsors, called The Manufacturing Universities Act, which would designate 25 "Manufacturing Universities" and provide them with grants of up to $5 million a year for four years to reshape their engineering programs with a stronger focus on advanced manufacturing. The resources would help universities promote their manufacturing engineering programs to attract more students into the field, promote more inter-disciplinary education, and allow engineering programs to purchase essential equipment to support hands-on, project-based learning, and working more on collaborative research projects with industry.

We also need to establish stronger university entrepreneurship metrics, collecting better data regarding commercialization, including: new business starts and spin-offs of new companies by faculty and students from universities, the amount of industry funding of R&D, patents issued, etc. Congress should direct the National Science Foundation to develop and implement metrics by which universities report such information annually.

In addition, we need more funding for commercialization activities. One way to do this would be to establish a set-aside program from federal extramural research for commercialization grants. In the House, the Startup America Act 3.0 (H.R. 714) introduced by Loretta Sanchez, Gerald Connolly, and Jared Polis, would set aside 0.15 percent of federal agencies' extramural research budgets to offer both (1) "commercialization capacity building grants" to institutes of higher education pursuing specific innovative initiatives to improve an institution's capacity to commercialize faculty research and (2) "commercialization accelerator grants" to support institutions of higher education pursuing initiatives that allow faculty to directly commercialize research in an effort to accelerate research breakthroughs.

However, we recommend that any such program be expanded to include state technology commercialization programs (either state governments or non-profit agencies they designate) as eligible recipients. Many states and regions fund their own technology transfer and commercialization efforts between their universities and the private sector. Federal funds could match these efforts at some percentage level to bolster their impact. Regardless of this, it will be important to expand funding for the Regional Innovation Program which prior Competes legislation authorized to "encourage and support the development of regional innovation strategies," which focus on commercialization, entrepreneurship, and startups. There is great demand for this program from programs all around the nation. In 2015, $15 million in grants were awarded. The program should be significantly expanded, to perhaps $75 million.

In a similar manner, a number of organizations throughout the United States are experimenting with novel approaches to bolster technology transfer from universities (and national laboratories) to industry and to accelerate the commercialization of university-developed technologies. Competes should support these types of novel approaches by including $5 million to fund experimental programs exploring new approaches to university and federal laboratory technology transfer programs. The program should be managed by the Department of Commerce's Office of Innovation and Entrepreneurship. Organizations would apply for the grants and winning proposals would be selected on criteria such as: 1) how innovative they are in demonstrating a new model; 2) recent documented success of their program; and 3) willingness to publicly disclose best practices learned from their programs and teach other U.S. organizations.

In addition, Congress should increase funding for the kinds of programs that are more focused on supporting university-industry research partnerships. While this is ideally achieved as part of an overall increase in federal R&D funding, it could be done in a revenue neutral way. In particular, the Engineering Research Center (ERC) and the Industry & University Cooperative Research Center (IUCRC) programs should receive a larger share of the overall NSF budget. There are 19 ERCs and 76 Industry/University Cooperative Research Centers, but their funding is quite modest. These programs can be quite effective at supporting innovation. For example, I/UCRC produces substantial cost savings for companies. When private companies conducted R&D projects through the I/UCRC partnership rather than in-house, they saved an average of $700,000 per project in 2014—up from $500,000 in 2012—thereby freeing up resources to be put to other, more effective, uses.

Competes should also support the NSF I-Corps program, which is an innovative effort to improve the "transmission belt" of transforming knowledge into innovation. As Senators Fischer and Coons have proposed, I-Corps should be established in statute, and authorized at least through 2020, and Congress should consider increasing its funding and expanding its availability to other federal agencies, including the NIH, DOD, DOE and USDA.

In addition, crowdsourcing and citizen science can empower individuals and organizations to participate in the scientific process by undertaking discrete, independent tasks to solve problems. For example, Cornell University's eBird project enlists people to record and report birds they say in order to improve scientific understanding of bird populations. Legislation proposed in the *Crowdsourcing and Citizen Science Act of 2015* would encourage and increase the use of crowdsourcing and citizen science methods within the federal government to advance and accelerate scientific research, literacy, and diplomacy. The Act would authorize agencies to use open-innovation tools to advance their missions, encourage the heads of agencies to work cooperatively on crowdsourcing or citizen science projects, increase inter-agency coordination, and strengthen the public's role as an active partner and meaningful contributor to the U.S. innovation engine.

Congress should also reform The Small Business Innovation Research (SBIR) program. Despite the fact that the SBIR program accounts for just over 3 percent of the federal extramural R&D budget, a recent ITIF study, *The Demographics of Innovation in the United States*, found that 60 percent of innovations included in the study created by companies with fewer than 25 employees utilized public grants through SBIR. Yet

despite its strengths, there are several programmatic reforms that could make SBIR an even stronger engine of commercialization activity.

First, SBIR Phase II awardees should be permitted to expend up to 5 percent of their Phase II funding on commercialization-oriented activities, such as market validation, IP protection, market research, and business model development, as Senators Coons, Gardner, and Gillibrand propose in the *Support Startup Businesses Act*. In the House, legislation similar in intent to foster commercialization activities has been proposed in an amendment to SBIR reauthorization legislation submitted by House Small Business Committee Ranking Member Nydia Velázquez. In addition, Congress should call on federal agencies with SBIR/STTR programs to standardize their commercialization data collection practices (whether around the DoD or new SBA model). The data is now collected individually by each agency in their own form and with different requirements, which both makes it more difficult for small businesses to comply or for useful insights to be gleaned from the data.

In addition, NIST's Hollings Manufacturing Extension Partnership (MEP) plays in important role in innovation. As ITIF writes in *International Benchmarking of Countries' SME Manufacturing Technology Support Programs*, a number of countries, across the developed and developing world alike, have manufacturing extension programs whose mission is to assist small to medium-sized enterprise (SME) manufacturers with implementing advanced manufacturing and quality processes and undertaking innovative new product development efforts. These programs: (a) promote technology adoption by SMEs; (b) conduct audits to identify opportunities for improvement in their manufacturing and operational processes; (c) support technology transfer, diffusion, and commercialization; (d) perform research and development in direct partnership with SMEs, and/or providing access to research labs; and (e) engage SMEs in collaborative research and development and/or technology-specific consortia. In the United States, client surveys indicate that MEP centers create or retain one manufacturing job for every $1,570 of federal investment, one of the highest job growth returns out of all expenditures of federal funds in the United States.

As a result, it is important to increase support for NIST's Hollings Manufacturing Extension Partnership (MEP), moving beyond the $130 million in funding the program received in FY 2016 (and even the current Congressionally authorized amount of $165 million in funding). As Senators Kelly Ayotte and Chris Coons have called for in *The Manufacturing Extension Partnership Improvement Act of 2016,* MEP funding should be increased to $260 million annually and the program authorized through 2020. In addition, a key to improving the effectiveness of the MEP program is to modify the cost share. Currently, after five years, centers are required to raise 2 dollars of non-federal funds for every federal dollar received. This relatively high ratio (higher than other federal matching grant programs), makes it harder for centers to fulfill their public purpose and respond to market failures. In particular, it makes it harder for centers to help start-ups and very young manufacturers and to support workforce training, export promotion, technology transfer efforts, and energy efficiency and environmental improvement. In addition, it makes sense to experiment with sectoral expansion of the MEP program into industries such as construction. As ITIF notes in a new report *Think Like an Enterprise: Why Nations Need National Productivity Strategies,* the measured productivity growth of the U.S. construction industry has actually been negative in recent decades. This is not because there are not technologies, tools, and practices the industry can use to get more productive. Much of the problem stems

from the fact most construction firms are very small and lack access to information about how to use these technologies effectively. An MEP extension could play an important role in remedying this.

High-performance computing (HPC) should be another area of focus. HPC refers to supercomputers and other technical computing systems that, through a combination of processing capability and storage capacity, can rapidly solve difficult computational problems across a diverse range of scientific, engineering, and business fields. HPC represents a strategic, game-changing technology with tremendous economic competitiveness, science leadership, and national security implications. The United States has long led the world in the development and adoption of high-performance computing systems, but as ITIF writes in *The Vital Importance of High-Performance Computing to U.S. Competitiveness*, U.S. leadership in high-performance computing is increasingly under threat as a growing number of nations, including China, the European Union nations, Japan, and Korea, have introduced concerted national strategies and announced significant investments in developing next-generation HPC systems. To safeguard continued U.S. HPC leadership, in July 2015 the Obama administration announced the National Strategic Computing Initiative (NSCI), a coordinated federal strategy for HPC research, development, and deployment and defines a multiagency framework for furthering U.S. economic competitiveness and scientific discovery through orchestrated HPC advances. Continued leadership in high-performance computing will require a steady, stable, robust, and predictable stream of funding. To ensure the NSCI can meet its targeted objectives, Congress should authorize and appropriate NSCI funding levels as requested in the administration's FY 2017 budget for FY 2017 and future years, with Congress funding NSCI and related high-performance computing initiatives at a level of at least $325 million per year over at least the next five years.

Finally, increasing the supply of STEM talent is another critical area Competes legislation rightly focuses on. Despite what some have argued, as ITIF has shown in numerous reports, there is a shortage of STEM workers, including in computer science.

A part of the solution will be increased STEM immigration. As a recent report by ITIF on the demography of U.S. innovation demonstrates, more than one-third (35.5 percent) of U.S. innovators were born outside the United States, even though this population makes up just 13.5 percent of all U.S. residents. Another 10 percent of innovators were born in the United States but have at least one parent born abroad. Immigrant innovators also are better educated on average than native-born innovators, with over two-thirds holding doctorates in STEM subjects.

Making it easier for more immigrants with STEM graduate degrees to become U.S. permanent residents will be important for driving innovation. Congress should also reform the EB-5 visa program which enables foreign investors to obtain a visa if they invest in a domestic enterprise and create or preserve at least 10 full-time jobs and invest at least $1 million. But many EB-5 projects simply displace projects that would have occurred anyway. Commercial property development does nothing for competitiveness or innovation. There is no real net benefit from allowing someone to obtain a visa by investing in a donut shop, golf course, or apartment building. These activities would be developed naturally by the market in the United States if there is in fact a demand for them. There is no shortage of entrepreneurs or capital for these kinds of non-traded business activities. In contrast, foreigners who want to immigrate to the United States to establish companies,

particularly technology-based ones, in traded sectors (e.g., manufacturing) are much more likely to represent a net addition to the economy rather than launch a business that just crowds out domestic activity. Therefore, Congress should consider narrowing and targeting the EB-5 program to be more focused on building technology-based businesses.

We also face a challenge in expanding the domestic pool of STEM talent, particularly among women and minorities. In ITIF's study, women represent only 12 percent of U.S. innovators. This constitutes a smaller percentage than the female share of undergraduate degree recipients in STEM fields, STEM Ph.D. students, and working scientists and engineers. Minorities born in the United States are also significantly underrepresented: U.S.-born minorities (including Asians, African Americans, Hispanics, Native Americans, and other ethnicities) make up just 8 percent of U.S.-born innovators. These groups constitute 32 percent of the total U.S.-born population. Despite comprising 13 percent of the native-born population of the United States, African Americans comprise just half a percent of U.S.-born innovators.

One reason to support robust funding for university research is that it enables universities to train more graduate STEM students. As ITIF has found, innovators in the United States are experienced and highly educated, and most hold advanced degrees in science and technology fields: four-fifths of innovators possess at least one advanced degree, and 55 percent have attained a Ph.D. in a STEM subject. Half of innovators majored in some form of engineering as an undergraduate, and more than 90 percent majored in a STEM subject as an undergraduate.

One path to expanding the number of highly qualified STEM workers is to expand the number of STEM-focused high schools. There are currently about 100 of these high schools in America, like Thomas Jefferson in Northern Virginia or Montgomery Blair in Montgomery County (which just won the national Science Bowl competition). These public STEM high schools provide students who have an interest and aptitude for STEM subjects with the opportunity to focus more intently on STEM subjects. They have also have been proven to be effective in helping minorities and students from socio-economic disadvantaged areas gain a high-quality STEM education. Given their effectiveness, we should set a goal to double the number of STEM high schools. Congress could do that by establishing a modestly funded challenge grant program that would allow states and cities to receive modest grants to help plan and establish new STEM high schools.

Congress should also do this for the establishment of new tech-focused universities, such as Olin College in Massachusetts or The Harrisburg University of Science and Technology in Harrisburg, Pennsylvania, or new types of STEM curriculum and programs at existing universities. One way to do this would be to expand support for NSF's Transforming Institution Grants program.

Another way the federal government could encourage STEM education is by providing prizes to colleges and universities that do best at retaining STEM students. This matters especially because 60 percent of those who enter college intending to pursue a STEM degree fail to graduate with one. Congress should authorize the National Science Foundation to establish a prize funds program to award to colleges and universities that have dramatically increased the rate at which their freshmen STEM students graduate with STEM degrees and that can demonstrably sustain that increase over five years.

In addition, the federal government should also require increased transparency from colleges and universities regarding the number of STEM applicants, prospective majors, and their retention rates in STEM subjects. There is some evidence that colleges and universities, especially state universities, could enroll more STEM students, but for a variety of institutional reasons do not do so. Better data regarding applications and retention will shed light on just how much of a problem this is.

Finally, one key factor in producing more PhD degrees in STEM, especially by U.S. residents, is the ability to support doctoral fellowships. But as Harvard's Richard Freeman notes, the number of NSF graduate research fellowships awarded per thousand of college students graduating with degrees in science and engineering went from over seven in the early 1960s to just over two in 2005. Today, the same number of NSF graduate research fellowships are offered per year as in the early 1960s, despite the fact that the number of college students graduating with degrees in science and engineering has tripled. But rather than simply expand funding for the NSF Graduate Research Fellowship program (funded at $102 million), Congress should create a new NSF-industry PhD fellows program. Currently the program provides up to three years of support over a five-year period and supports approximately 3,400 students per year at $40,500 per year. The new NSF-industry program would work by enabling industry to fund individual fellowships of $20,250 with NSF to match industry funds dollar for dollar. Congress should allocate an additional $21 million to a joint industry-NSF STEM PhD fellowship program. This would allow NSF to support an additional 1,000 graduate fellows.

In summary, Competes reauthorization is an important step to take to ensuring that America does not lose its lead in innovation. Thank for you inviting me to testify before the Committee today.