Carnegie Mellon University

**TESTIMONY SUBMITTED TO
THE U.S. SENATE COMMITTEE ON
COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SPACE, SCIENCE, AND COMPETITIVENESS
BY
DR. ANDREW W. MOORE
DEAN, SCHOOL OF COMPUTER SCIENCE
CARNEGIE MELLON UNIVERSITY
NOVEMBER 30, 2016**

Thank you Chairman Cruz, Ranking Member Peters, and Members of the Subcommittee for convening this important hearing on Artificial Intelligence (AI). I am honored to be here and to be joined by colleagues who are advancing the science, technology, business models, critical applications, and policy considerations of AI in the service of the United States and humanity.

My name is Andrew Moore. I am the Dean of the School of Computer Science at Carnegie Mellon University and former Vice President at Google responsible for Machine Learning technology. I appreciate your leadership in focusing on the future of science, innovation, and American competitiveness and on the role that AI can play. The policies and strategies we adopt over the next several years will determine if the United States wins the race to lead this technological revolution as well as the resulting benefits for our citizens.

Introduction: Perspectives on the Future of AI from a Journey in Computer Science

Building upon fifty years of research, strategic federal investments, dramatic advances in machine learning, and the explosion in available digital data, we no longer describe AI as a technology from the future: it is around us in our phones, our vehicles and in defense of our borders. AI tools are already making doctors better at diagnosing diseases and ensuring patients obtain the latest effective treatments.

AI-empowered personalized learning will enable teachers to better reach and engage every student. Powerful new AI cyber tools will provide a new and more definitive defense against a world increasingly populated by hackers intent on criminal or state-sponsored attacks on American institutions, businesses and citizens. Adaptive, learning robotic systems will enable small manufacturers to cost-effectively change product lines more rapidly—even realizing mass production economies from “quantity one” to compete with foreign firms utilizing cheap labor. The ability to combine autonomous vehicles with public transit will unlock urban congestion, transform land use, enhance safety, and enable cities to focus on the most critical human elements of mobility. And, the potential applications of AI as powerful tools in national defense and homeland security will make us safer, even in the face of growing threats. In each of these areas, powerful opportunities exist to eradicate the barriers of distance, economic isolation, and limited economic opportunities, as well as making us a smarter, more productive, healthier, safer nation.

Some economists assert that increased deployment of AI could represent a powerful economic stimulus for the nation—perhaps adding as much as 2 points to annual GDP growth by 2035.[1] There are also economists who warn that the advance of AI applications could exacerbate income inequality and threaten a wide number of middle income jobs.[2]

I am not an economist by training. I bring to this hearing perspectives shaped by my journey over three decades as a computer scientist and a technology business leader. As a university researcher I had the opportunity to develop machine learning capabilities that enable emergency room physicians to better predict the illnesses and patient levels they are likely to confront as weather and virus outbreak patterns evolve. This experience provided a window on how powerful AI applications can be to improve the delivery of vital services to those in need.

At Google I helped develop advanced machine learning platforms to more effectively connect consumers to information by making search engine algorithms smarter and more powerful. That experience also taught me how AI tools can democratize access to information and unleash the energy of entrepreneurs to capitalize on the power of these platforms to bring products to consumers in a way that would have never been possible before.

For example, enabling consumers to see the 200,000 new dresses that are produced each day in the world helps to unleash the creativity and entrepreneurship of dress makers and fashion designers in an unprecedented way, whether they are large companies or a small startup, in a major city or a rural community.

But, as this Committee knows well, we face far broader and more daunting and important challenges as a nation than matching consumers with dresses.

Now, as Dean of the #1 Computer Science School in the U.S., I have the wonderful opportunity to engage with a new generation of students—and their faculty mentors—who are drawn to computer science because they want to focus their careers on applying AI to tackle our biggest societal challenges. They arrive at this with the clear eyed recognition that, as has been true with all new innovation, they must also address the potential negative impacts these technologies may bring. These experiences make me very optimistic that we can harness the power of AI to grow our economy and improve our quality of life while also acting definitively to mitigate any potential disruptions this new technology, like any new technology, can bring. New technology will always come. We must contribute to its use for good.

My journey as a computer scientist leaves me certain that AI can create fundamentally new economic opportunities and be a powerful resource for addressing our most pressing challenges in areas of security, health care, better food production, and a new era of growth in manufacturing. At the same time, it can fundamentally transform the nature of work, as well as create new challenges in areas such as privacy. The key is a focused national strategy to nurture and attract the best talent, including applying new AI learning tools to aid workers in need of retraining; to enhance discovery and commercialization; and to create a business and regulatory environment that rewards innovation.

Carnegie Mellon and the AI Revolution

My perspective has been heavily shaped by the culture of discovery at the School of Computer Science at Carnegie Mellon. The development of Artificial Intelligence was launched 60 years ago at a seminal gathering at Dartmouth University in the summer of 1956. Two of the four scientists who led that session, Allen Newell and Herbert Simon, were CMU faculty and had already created the first AI program. Since that time, with strong support from federal research agencies, our faculty have pursued disruptive innovations that have help fuel the development of AI. These innovations include multithreaded computing, speech and natural language understanding, computer vision, software engineering methodology, self-driving robotic platforms, distributed file systems and more.

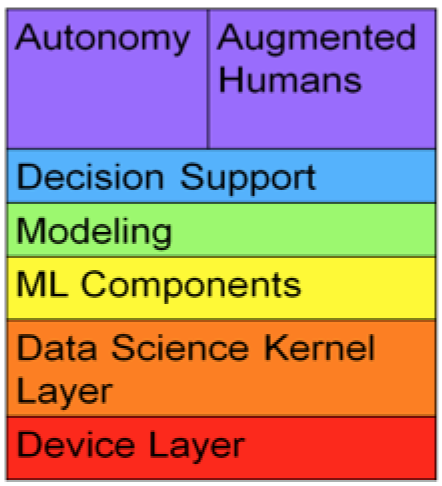
Today well over 100 faculty and 1,000 students at Carnegie Mellon are engaged in AI-related research and education. In addition to advancing breakthroughs fundamental to the building blocks of AI systems, Carnegie Mellon faculty and student researchers have applied advances in AI to the early detection of disease outbreaks, combating sex trafficking rings, detection of emerging terror threats in social media, and to the development of cognitive tutoring tools that are now deployed in middle schools, high schools, and colleges in every state in the nation. CMU alumni and faculty (typically on leave) hold leading positions in each of the major companies driving AI development, including at Microsoft, IBM, Google, Amazon, and Apple. CMU spin-off companies have been a catalyst to advancing AI innovations.

Fundamental Building Blocks of AI Systems

AI is defined as "the scientific understanding of the mechanisms underlying thought and intelligent behavior and their embodiment in machines." [3] As we strategize on the next AI steps at Carnegie Mellon University, it helps us to break AI research into two broad categories: Autonomous AIs and Cognitive Assistant AIs. An Autonomous System has to make low level decisions by itself, for example a car that only has half a second to react to a collision simply cannot wait for a human. Or a constellation of satellites that has lost communications with the ground needs to figure out what they should be observing and transmitting to the ground while trading off the need to protect their advanced sensors against an energy attack. Cognitive Assistants, on the other hand, work hand in hand with a human: our smart phones telling us how to get to our kid's dental appointments are a simple example. Much more advanced examples include CMU Faculty Member Dr. Sidd Srinivasa's work on intelligent robot arms controlled by humans in wheelchairs with high spinal cord injuries.

AI involves transforming raw data--often massive amounts of raw data--into usable, actionable information. This cycle is known as "data to knowledge to action." The graphic below captures the "stack" of elements that constitute AI. It is intended to show all of the areas that are important for ongoing AI research and development, to continue to expand our science and technology.

The foundation is the device and hardware layer that includes powerful computer processing and storage capabilities. The data science kernel layer includes architectures for processing massive amounts of data--essential to managing the explosion of digital data available through the internet and the growing global network of sensors. The Machine Learning (ML) layer includes algorithms that automate the detection of patterns and gather insights from large data sets far faster than humans could, even in many lifetimes. The modeling layer includes statistical methods and tools for prediction—the ability to move from the recognition of patterns in data to the ability to understand how complex real-world systems and structures behave. We mean "systems" in a general sense: from biological entities, to behaviors, to farms, to cities, to societies, to the cosmos. One example system is triage of inspection of cargo by US Customs. Another is detecting and managing the response to potential false alarms by emergency responders. The decision support layer includes management information systems software that assembles facts, diagnoses status and evaluates potential actions. As an example, decision support applications are vital to enable autonomous vehicles to rapidly react to changing traffic patterns. They are also in use in flexible manufacturing systems in American factories. Decision support capabilities also include tools to detect human emotion and intent and create profiles from the physics of speech. Each of these layers builds on the layers below it.



These building block layers power the two major application areas of AI—autonomous systems and capabilities to augment human performance. One application developed by a team of Carnegie Mellon University School of Computer Science researchers, led by Rita Singh, illustrates how the components of the AI "stack" can be applied to dramatically enhance intelligence analysis and crime-solving capabilities of organizations that deal with voice-based crimes.

The world is increasingly communicating through voice: an estimated 700 centuries worth of speech is transmitted over cellphones alone each day. While more people are talking than ever before, even more people are listening. There are 4 billion views of YouTube videos daily. These and other internet-accessible videos have voice embedded in them. The tremendous outreach of voice today allows for a dangerous world where more and more crimes can be committed and propagated through voice alone. These crimes include those that affect people's personal security, such as harassment, threats, extortion through fraudulent phone calls etc., all the way to societal crimes that affect national security, like hoax calls, criminal propaganda, communication in organized crime, terrorist indoctrination, etc.

The CMU team is developing technologies that utilize the power of machine learning and AI to profile people through their voices. They are able to describe the physical appearance of a person, background and demographic facts about the person, and also the person's surroundings entirely from their voice. In recent work with the US Coast Guard Investigative Services, the team analyzed scores of Mayday calls from hoax callers transmitted over national distress channels, and has provided physical descriptions of the perpetrators, and of their location and the equipment used that were sufficiently accurate to enable significant success in the investigative process.

It is noteworthy that the US law enforcement and security agencies as well as first responders are faced with hoax calls on a daily basis, and these collectively cost the nation billions of dollars in misdirected and misused resources each year. Hoax calls are just one example. The ability to track and describe humans through their voice is useful in several disciplines of national intelligence, where voice is part of the intelligence information gathered.

Our work builds on the fact that humans can make judgments about people from their voices, like their gender, emotional state, their state of health, and many others. The CMU team utilizes powerful AI techniques to achieve super-human capabilities that enable machines to make faster, more accurate, more abundant and deeper assessments of people from their voices. This is made possible by advances in AI, computing, machine learning and other related areas, and over two decades of developments in automatic speech and audio processing capabilities at CMU. The team hopes to be able to build physically accurate holograms of humans from their voices in the future.

This work, and that of many others, demonstrates the power of AI to dramatically help with judgments that humans make and in doing so augment human capabilities. This case is also illustrative of what we at Carnegie Mellon believe will be a dominant pattern of AI deployment: work in close synergy with humans. The nature of work tasks will evolve, potentially dramatically in certain cases, and will demand new and different skills. AI systems that augment and complement human capabilities will help us as individuals and as a nation through this transition and beyond.

Similar examples of AI already touch our daily lives. Smartphone applications that personalize services are based upon AI algorithms. Other AI applications are helping forecast crop yields, analyzing medical samples, and helping deploy police and fire resources. Autonomous systems are at work on city streets, on American farms, and patrolling the sea and air for our national defense.

Intelligent AI systems will also include mobile robots and intelligent processing and decision-making among the sensory and actuation capabilities of the "internet of things." AI systems may always have limitations and will therefore be in a symbiotic/coexistence relationship with humans, and with other AI systems. Designing and building these systems and relationships is a fruitful area for advances.

Perhaps most critically, judgments that humans make in the area of national intelligence are vital to our safety and security. Combined with the wealth of data available today (including through crowdsourcing), AI is the future power source of these decisions--processing far more possibilities and scenarios than humans could alone, and working closely with humans to keep us protected.

And, we are just at the start of this AI revolution.

The Inflection Point and Emerging AI applications and Capabilities

Two specific breakthroughs in the last five years have created the inflection point that makes this hearing so timely and essential. The first is the rapid advancement in digital datasets that are central to AI applications. Current estimates of the world's digital data are approaching 1.3 zettabytes or about 1.3 trillion gigabytes.[4] Fueled by both research and applications, as well as a strong commitment to increasing access to government data, this explosion includes digital biomedical data, mapping data, traffic data, astronomical data, data from sensors monitoring machines and buildings, and data from social media capturing consumer trends from restaurants to travel patterns. Advanced AI applications are catalyzed by the availability of this data.

The second major breakthrough is the development of *deep learning* techniques in machine learning. Deep learning involves a statistical methodology for solving problems in very large and very complex datasets. The term "deep" is derived from the ability of these learning methodologies to automatically generate new models and abstractions of the data. Deep learning brings about the potential for self-learning capabilities that are the central to dramatic advances in AI applications. More critically, deep learning creates the potential for advancing beyond narrow AI—applications focused on one specific task—to general AI that creates a platform for undertaking a wide range of complex tasks and responding in complex environments.

Thoughts on the Policy Implications of the Emerging AI Revolution

The potential transformative impact of these future applications of AI to transform our economy, generate economic opportunity and address critical challenges to our security and quality of life is clear. However, the future--especially the future of U.S. leadership in this area--is not assured. Drawing upon my experiences as a researcher in machine learning, a technology business leader committed to developing AI capabilities, and now as a computer science dean engaging with the aspirations of faculty and students, here are selected thoughts on some of the key elements of a strategy to ensure continued U.S. leadership.

Winning the Talent War

We need a comprehensive set of policies and incentives that addresses the skills needed to win in the AI-driven economy of the 21st Century. These policies must address the talent pipeline, from computer scientists *per se* to the workers impacted by new applications.

The starting point is a recognition that we are already engaged in an international war for talent. Based upon my experience in a leading technology company, a computer science graduate with expert level AI training adds between $5 and $10 million to the bottom line of a company.

These people are very rare for two reasons. First, they need to have the natural abilities to deal with logic and math and software on a massive scale. Second, they need to survive very intense training that covers many disciplines at once, including algorithms, robotics, security, ethics, advanced probability and human-centered design.

As a result of the rarity of these skills, young AI experts are being heavily competed for around the globe. We see crazy bidding wars taking place from Beijing to Boston to Pittsburgh to Paris. The United States is not winning in the rate of production of these young experts, and we have recommendations below on how to get back on track.

Secondly, AI is one area where international innovation is coming primarily from universities. It is North American professors and their graduate students who have introduced all of the following great advances in AI in recent years: self driving, deep learning, advanced human recognition, emotion detection, provable AI safety, spoken dialog systems, autonomous helicopters, intelligent traffic control, and many others. These have all been taken into the corporate and military worlds through technology transition and through many professors and students transitioning with their technology. The success of AI professors has had great benefit for the economy and security, but it is getting harder and harder to entice new AI geniuses to replenish the ranks of North American professors. The concerns about their retention are twofold: it is increasingly lucrative to abandon an academic position and also increasingly hard to raise funding for university research. These professors are very important because they are the ones producing thousands of AI experts for the country every year. If the US loses many of these professors--and fails to continue the pipeline from graduate school--the supply if US AI experts will dry up.

We will need a balanced set of policies and incentives to ensure that we can provide the talent companies need while securing our long term capacity for research and innovation. This requires recognizing the imperatives of retaining top faculty and supporting graduate students. To support faculty retention we may wish to consider strategies utilized by some of our international competitors who issue competitive “star grants”: multi-year awards to the top 100 researchers to enable them and inspire them to continue their academic research careers. To maintain our base of graduate students who are central to our research leadership, consideration should be given to expanding fellowships focused explicitly on AI-related fields and expanding the number of multi-year, broad-based research awards that enable faculty to provide support for students throughout their graduate studies and within ambitious projects.

We also need to move aggressively to build the pipeline of computer science talent. The Every Student Succeeds Act, the ESEA reauthorization passed by this Congress, makes an important start by emphasizing the importance of computer science in STEM education. It is also increasingly vital to foster stronger collaborations across the education spectrum: for example between research universities and community colleges and between higher education institutions and K-12 to enhance curricula, teacher education, and student engagement.

As has been vital in all periods of discovery and innovation, it is essential that the United States retain its ability to attract the best and brightest talent from around the world to study here, work here, perform world-class research and development here, and start American companies, all of which serve as engines for growth and national prosperity.

For example, Carnegie Mellon is now engaged in a collaboration with Microsoft's TEALS program and Pittsburgh Public Schools to enhance the ability of teachers to introduce computational concepts throughout the curriculum, by drawing on volunteer computer scientists who understand the importance and urgency of computer science education. Similar collaborations are taking place across the nation. We will need to explore how best to incentivize formal and informal learning initiatives in all communities.

Winning the talent war will also require fundamentally new approaches to workforce training. Many workforce programs tend to focus on shifting individuals to new careers or training workers to operate a specific type of equipment. Neither model is likely to be completely applicable to empower workers to thrive as AI applications impact a wide range of industries.

It will not be necessary for workers to have a computer science degree to thrive in the AI economy. But the capacity and skills to work with advanced machines and understand computational processes will be essential. This will require a mix of technical skills and an understanding of data analytics. This new workforce environment is already taking shape. There are construction firms using advertisements highlighting the opportunity to work alongside robots as a benefit in their efforts to attract skilled workers. Advanced manufacturing is another area that will build on the strength of robotics, while requiring more and more tech-savvy workers.

We have two great resources in creating a skill development environment for the AI era. First, more than in any other period of technological development, we have the power of intentionality. We can advance AI research and innovations with explicit consideration of the human engagement and models of human/machine interaction in mind. It will be vital for workers and workforce development professionals to become integral to the AI research process to realize this opportunity.

Second, the AI revolution itself will give us unprecedented tools for workers to develop new skills. AI is already creating the capacity to personalize training for the individual worker, for example by understanding and modeling each learner's path through a curriculum, and blend technical and academic content that is targeted to the specific job. Combined with innovations like wearable computing devices, entirely new, more powerful approaches to on the job training are being deployed.

Creating a National Framework for AI Research and Innovation

The amazing AI application that describes individuals solely through their voice is built on over 20 years of federally funded research. The next wave of breakthroughs in AI will take place in academic labs, startups and major companies. We will need a national research and innovation framework tailored to this ecosystem.

The starting point is federal research focused on the critical fundamental gaps impeding AI development. The recent reports prepared by the White House National Science and Technology Council, with extensive input from academic and industry researchers, is an excellent starting point for identifying cross-cutting foundational research areas.[5] As noted in the NSTC reports, we will need to develop a science of safety, dependability, and trust for AI systems. Traditional verification methodologies and approaches are not fully applicable to systems that learn and continually improve. This effort will require both investments in advancing new methodologies and the creation of test beds.

This focus on the science of safety and trust must also include engagement on issues of privacy and the ethics of AI deployment. Through a gift from K&L Gates, Carnegie Mellon University is launching a new initiative focused on ethics, trust, and privacy. Federal support that helps engage computer scientists, social scientists, legal and policy experts, and industry leaders will also be key.

Another critical gap highlighted in the White House reports involves the imperative for continued research focused on systems for human-computer interaction. Research advances will ensure the effective design of AI systems with user friendly interfaces that work seamlessly alongside humans in a variety of settings. Future AI systems must be able to adapt to different challenges, such as providing flexible automation systems that switch from worker to machine operation and systems designed to address situations where the operator is overloaded by the complexity of his or her tasks.

Finally, it will also be critical to invest in the foundational capabilities for scaling AI systems. The most critical need is to collaborate across industry and government to improve access to the knowledge that fuels the capabilities of AI systems. One promising dialogue in this area is well underway. Representatives of agencies, universities, and industry have worked on the development of a collaborative AI infrastructure initiative initially called The Open Knowledge Network (TOkeN). TOkeN would provide a vital core infrastructure for AI development—interfaces to large data and knowledge bases that can accelerate the ability of AI systems to create products and services, broadly speaking, in health care, education, climate and planetary sciences, energy, manufacturing, and a host of other areas. TOkeN would be an open web-scale, machine-readable knowledge network aspiring to include every known concept from the world of science, business, medicine, and human affairs—including both raw data and semantic information. The creation of TOkeN would enable the rapid expansion of AI applications for diagnosing disease, designing new products or production processes, and serving our citizens in many other ways.

The collaborators intend that ToKeN, if implemented, would represent the kind of foundational infrastructure that was created to launch the Internet era. In the early 1980's, proprietary, disconnected islands of technology prevented the scaling of applications and services--the Internet connected them. Today, islands of proprietary and disconnected data and knowledge sets are impeding academic research and industry innovation. With a relatively limited investment we can create the foundation for scalable AI development and accelerate innovation.

In addition to a focused research agenda we will need a research framework that recognizes the nonlinear nature of AI innovation. Basic and applied development is taking place in universities, start-ups, and companies. We need to incentivize collaboration across this ecosystem. The Computing

Community Consortium (CCC) has advanced thoughts on how new models of public/private, industry/academic partnerships can be crafted to meet this challenge.[6]

One powerful tool to stimulate this collaboration is federal support for grand challenges that bring together companies, students, faculty, and often state and local governments to apply innovations to address particular critical societal objectives and opportunities. The DARPA grand challenges have helped advance both the development of autonomous vehicles and automated cyber defense capabilities. AI grand challenges focused on issues such as education, manufacturing, or opportunities to expand economic opportunity in rural areas would have a catalytic impact on both fundamental research and commercial applications.

<u>Align Research and Development with Smart Regulatory and Procurement Initiatives</u>

The development and scaling of AI innovations will demand new regulatory paradigms. Initial positive steps have been undertaken to help advance the deployment of autonomous vehicles but we must summon federal, state, and local, as well as industry and citizen collaboration to craft smart regulations that advance AI and tap its power to more efficiently realize public policy objectives for health and safety. Without progress on regulatory issues AI development will stagnate or, more likely, innovations born in the U.S. will take root abroad, impeding national competitiveness. Combining regulatory experiments and test beds with strategic procurement initiatives to help advance AI products and services will be vital.

<u>We need an "All In" Approach</u>

Synergistic engagement among the federal government and our "laboratories of democracy," the states, has been a powerful tool for U.S. science since the efforts to revitalize the competitiveness of the U.S. semiconductor industry in the 1980's. For example, federal research and commercialization investments in the life sciences have catalyzed billions of dollars of state and local initiatives.[7] These state and local efforts help augment research infrastructure, train workers, expand K-12 curricula, and incubate and nurture startups. Engagement of the states in AI policy is particularly critical as we seek to advance STEM education and workforce training initiatives, foster an innovative regulatory environment, and continually cultivate a vibrant environment for incubating AI startups.

Conclusion

Thank you once again for convening this hearing and for the opportunity to join my distinguished colleagues to share thoughts on the direction and implications of advances in Artificial Intelligence. My experiences as a researcher, business leader, and dean lead me to believe that applications of AI will begin to accelerate rapidly across a host of industries. I believe these applications will expand economic opportunity and contribute to addressing major societal challenges in health care, food production, security and defense, energy, and the environment and education. The "democratizing" power of AI applications to bring new capabilities to individuals on the job, in schools, and in our homes and communities is at the heart of this potential.

My experiences have also made me greatly aware that we are in a global race for talent and innovation. Focused attention on the impact these applications may make on the nature of work in a host of industries and the challenges they bring to our privacy is vital. This will require drawing upon the very best American traditions of collaboration across government, industry and academia.

It will also require research investments to advance innovation in key gap areas that are core to advancing AI and sparking innovation, entrepreneurship and new products and services. We will need an innovative focus on regulatory environments that will be transformed by AI. We must nurture our talent resources: from retaining top researchers, to attracting the best and brightest from across the globe, to creating a national pipeline to nurture students in every community and creative new approaches to support existing workers. I speak with confidence in stating that the university research, education, and industry communities stand ready to engage in helping to ensure that the AI revolution expands opportunities to all Americans.

End Notes and References

1. Why Artificial Intelligence is the Future of Growth, Mark Purdy and Paul Daugherty, Accenture, 2016, P.19.

2. See for example the report on research conducted by Forrester, "AI will eliminate 6% of jobs in five years, says report," Harriet Taylor, CNBC, September 12, 2016.

3. See American Association for the Advancement of Artificial Intelligence, http://www.aaai.org/

4. "World's internet traffic to surpass one zettabyte in 2016," James Titcomb, The Telegraph, February 4, 2016.

5. The National Artificial Intelligence Research and Development Strategic Plan, National Science and Technology Council, Networking and Information Technology Research and Development Subcommittee, October 2016. See pages 16-22.
and
Preparing for the Future of Artificial Intelligence, National Science and Technology Council, Committee on Technology, October, 2016.

6. The Future of Computing Research: Industry-Academic Collaborations Version 2, Computing Community Consortium, 2016.

7. For example, in 2001 Pennsylvania committed $2 billion in its tobacco settlement funding allocation to support research by universities and health research institutions, support venture investments in the life sciences and fund regional cluster initiatives. In 2008 Massachusetts committed $1 billion for a 10 year initiative for capital investments in research infrastructure and start-ups. Michigan invested $1 billion in 1999 over 20 years to support the growth of life sciences corridors. For a summary of some of these initiatives and other state efforts see "Successful State Initiatives that Encourage Bioscience Industry Growth," Peter Pellerito, George Goodno, Biotechnology Industry Organization (BIO), 2012.