Testimony of

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Chairman Shuster, Ranking Member Larsen, and members of the House Armed Services Committee Defense Business Panel, my name is Dr. Stephen E. Cross and I serve as the Executive Vice President for Research of the Georgia Institute of Technology. I am honored by your invitation to present this testimony to provide a perspective on the role that universities, research institutions and laboratories play in developing innovative technologies for the Department of Defense (DoD), and specifically how those organizations support DoD laboratories and private sector companies in transitioning research from academic concept into production. I will do this from the perspective of someone who has served in leadership positions at two major research universities, has participated in many related studies on DoD advisory boards, and has held several leadership positions in DoD research organizations. I will first provide a brief overview of my background and that of my university. I will then cite examples of how the results of sponsored research benefit and support DoD organizations, how these results transition to use in the DoD and the private sector and provide a brief overview of innovation best practices and how they are applied in an overall strategic approach at a major research university. The summary section will explain why this is critically important in our current uncertain and rapidly changing world.

Personal and University Background

My work for the past 29 years, including my R&D assignments as a military officer, has focused on technology transition. I currently serve as a member of the Defense Science Board (DSB) and I am a past member of the Air Force Scientific Advisory Board (AFSAB) and the Defense Advanced Research Projects Agency (DARPA) Information Science and Technology (ISAT) panel. I have led and participated in many studies related to defense research and technology transition including two recent studies on the topics of disruptive innovation and organizational adaptability. I received a Ph.D. degree in electrical engineering from the University of Illinois Urbana-Champaign in l983 while serving as an officer in the United States Air Force. I retired from the military in 1994 while serving as a program manager at DARPA. The research I supervised at that time was recognized for its innovation and impact through accelerated transition into fielded applications during Operation Desert Storm. Subsequently, I was a research faculty member and the Director and CEO of the Software Engineering Institute (SEI) at Carnegie Mellon University in Pittsburgh, Pennsylvania until 2003. The SEI is a DoD Federally Funded Research and Development Center (FFRDC) focused on the transition of research on best practices in software engineering and cyber security. Over 5,000 organizations worldwide have adopted practices attributable to SEI related research.

In 2003, I became the director of the Georgia Tech Research Institute (GTRI), the applied research arm of the Georgia Institute of Technology (or Georgia Tech as it is more commonly known). Unlike FFRDCs located at major universities, GTRI is constituted as a college level unit within Georgia Tech and competes with the rest of the research community for sponsored awards. With a staff of more than 1,500 and unique laboratory facilities on the main campus (including space for classified work), it supports an extensive program in defense-focused research for many of the DoD laboratories and many other research organizations (e.g., DARPA). Its technical staff consists of subject matter experts (SMEs) who also hold

faculty status within Georgia Tech. As SMEs, the faculty is equally comfortable engaging in fundamental research with their college colleagues in a broad area of technical areas as they are in applying research results to solve hard problems for DoD clients and other industry stakeholders. Prohibited by policy as a nonprofit state-supported institution, GTRI does not compete with industry, but has effective approaches (e.g., transition of production and manufacturing plans, information dissemination programs) to facilitate technology transition and adoption. As stated, GTRI is an integral part of Georgia Tech.

I assumed my current role in 2010, a position responsible for guiding and implementing a research strategy for the Institute. Georgia Tech is one of the nation's top research universities, distinguished by its commitment to improving the human condition through advanced science and technology. From its Atlanta base, Georgia Tech provides a technologically focused education for more than 20,000 undergraduate and graduate students. Its engineering college is the largest in the United States and it supports affiliated degree programs at the undergraduate and graduate levels in architecture, business, computing, humanities and the liberal arts, policy and international affairs, and the sciences. Its professional and executive education program is one of the largest in the country. Georgia Tech leverages its state-supported economic development arm, the Enterprise Innovation Institute with its staff of 225 economic development professionals, to assist in the transition and use of research results in various commercial markets that are strategically important to the State of Georgia.

Research Strategy of Georgia Tech

In FY2011, Georgia Tech's research expenditures were $643 million, of which 65% was attributable to federal sources. It ranked as the #3 producer of patents in Georgia, behind AT&T and Kimberly Clark,[1] and #8 in the country among research universities in economic development impact.[2] During this year, it was granted 78 patents and it created 17 new companies through its internal incubator. These companies attracted $100 million in start-up funds from the private sector and resulted in 583 new jobs. In addition, Georgia Tech managed 980 contracts with companies and transitioned 127 technologies. The State of Georgia also invested directly to support research and economic development (including support for research and labs and other infrastructure). Collectively, the non-defense resource base represents significant leverage and amplification of funding provided by defense research organizations via competitively selected awards.

Georgia Tech pursues a research strategy across its integrated research enterprise focused both on leading-edge, use-inspired research and economic development. This strategy recognizes that technology development and transition is not a sequential and linear process. Georgia Tech pursues a concurrent strategy focused on strategic theme areas, such as national security, biomedicine, food processing, and manufacturing. Concurrency means that teams of faculty, graduate students, application and economic development experts, and professional staff work together to define and pursue grand challenges, meet and exceed the expectations of research sponsors, foster early engagement with industry, and accelerate the maturation and transition of technology. It should be noted that to accomplish this, a balance is required between high-risk, discovery-focused research, and economic development and transition activities. Not every research task is successful. Research is an experimental pursuit where new insights and fundamental learning often come from failure. The balance sought is to engender and support a culture that blends high-risk, discovery-focused research with early identification of commercialization potential. Another way of stating this is that Georgia Tech's approach to technology transition blends

[1] http://patft.uspto.gov/
[2] http://www.autm.net/FY_2009_Licensing_Activity_Survey/5879

best practices in sustained and disruptive innovation.[3] This will be further illustrated throughout the remainder of this testimony.

A key reason that Georgia Tech is able to achieve such economic development impact is due to an alignment of federally sponsored programs, support from the State of Georgia, and an active industry outreach program. Through a unique public-private partnership called the Georgia Research Alliance,[4] the State of Georgia provides support for 65 eminent scholars at Georgia Tech and four other universities in Georgia, and for Venture Lab incubators at each Georgia research university. In addition, with state support, Georgia Tech manages the Advanced Technology Development Center which supports over 500 small companies through the state, hosts the NIST Manufacturing Extension Program in Georgia, and provides the home site for the state's Department of Economic Development.

Furthermore, the state has partnered with industry to create unique venues[5] to support key markets to Georgia, such as a building for innovation and research translation to the food processing industry.[6] Similarly, with the help of a construction grant from that National Institute of Standards and Technology, Georgia Tech is constructing a Carbon Neutral Energy Systems building that will serve as a model for collaborations between research universities and global energy companies.[7] As noted by Google CEO Eric Schmidt in a June 2010 CNN special on innovation, such facilities are crucial for supporting technology transition, recognizing and supporting game changing innovations, and in realizing economic development impact.[8]

Examples

Three examples will illustrate how Georgia Tech supports and translates defense research through technology transition and innovation programs. The practices are codified by a national academies sponsored private-public partnership known as the Government-University-Industry Research Roundtable (GUIRR).[9] It is also illustrates the direct benefits afforded by the Bayh-Doyle Act of 1980. As described in a background paper by the American Association of Universities,[10] before 1980 there was little demonstrable economic benefit from federally sponsored research. The Bayh-Dole Act in 1980 provided that universities and other non-profit research organizations can elect to take title to inventions arising from federally-funded research provided that they take steps to ensure utilization. Among other things, Bayh-Dole requires institutions to license new technologies for US manufacture (or in the US) and retain for the US Government the right to practice inventions royalty-free for government purposes.[11] The number of patents issued to US universities doubled by 1985 and the most recent economic development indicators cited by the Association of University Technology Managers (AUTM)[12] shows incredible rapid escalation since that time.

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[3] Sustained innovation involves incremental enhancements to products and/or processes. Disruptive innovation involves game changing breakthroughs. As described by Clayton Christenson in his book *The Innovator's Dilemma* organizations that have a commanding market position typically focus on incremental innovation in order to meet near term stakeholder need and to maintain market share. It is not uncommon for such organizations to miss the next big thing. There are many examples of this throughout military history too.

[4] http://www.gra.org

[5] Often called "skunk works" patterned after the famous Lockheed facility from an earlier era, see Rich, B. and Janos, L. (1996). Skunk Works. Boston: Little, Brown & Company, ISBN 0316743003.

[6] http://www.fptd.gatech.edu

[7] http://www.gatech.edu/newsroom/release.html?nid=48988

[8] http://www.youtube.com/watch?v=UsxMxXXp-dA

[9] http://sites.nationalacademies.org/PGA/guirr/index.htm

[10] AAU Report on *Understanding University Technology Transition*, www.aau.edu/WorkArea/DownloadAsset.aspx?id=1158

[11] The second part (requirement to license for US manufacture) is an often overlooked, but crucial feature of this legislation.

[12] http://www.autm.net/FY_2009_Licensing_Activity_Survey/5879

Example 1 - Direct Support to the DOD: Georgia Tech pursues a broad array of basic, applied, and development R&D activities in partnership with the DoD laboratories and research organizations. Three excellent recent examples involve sensor technology, advanced information technology, and technology related to autonomous systems.[13] In each area, Georgia Tech's fundamental research has been well described in the technical and popular literature. Space will not be allocated here to describe it but references are provided. In the case of sensor technology, Georgia Tech manages an information dissemination and support service for the Defense Technology Information Center (DTIC) called the Military Sensing Information Analysis Center (SENSIAC).[14] SENSIAC holds 10 conferences a year for the defense research community and it also provides direct transition services and information to defense organizations and industry.

Similarly, the extensive body of information technology and electronics work has resulted in quick response innovation programs for DoD logistics centers and the National Guard. A well-known result is Falcon View, the standard military mission planning mapping system.[15] Another recent example shows how GTRI responded quickly to an urgent operational need by going from design, test, and delivery of production plans for an electronic warfare upgrade for the A-10 aircraft deployed to Afghanistan.[16] GTRI produced production plans that were made available to DoD contractors for the full-scale production. Similarly, GTRI also works directly with the National Guard, including a forward presence in Tucson, AZ to support rapid integration of new technologies to the F-16 aircraft.

In the area of autonomous systems, Georgia Tech faculty and students are engaged in leading edge research.[17] Significantly, GTRI is also involved in thought leadership about how to bring modeling and simulation techniques to support improvements through its work on a test and evaluation roadmap for the DoD. These are but a few examples of how Georgia Tech engages in leading edge research sponsored by the DoD and works aggressively to accelerate the maturation and transition of results to use in the defense community.

Example 2 – Leveraged Benefit to DoD Research: Georgia Tech receives research sponsorship from many other federal sources and industry stakeholders. For example, Georgia Tech has participated in several Engineering and Research Centers (ERCs) and other research centers for the National Science Foundation in areas spanning nanotechnology, materials, and biomedical devices.[18] Similarly, Georgia Tech is engaged in leading-edge energy research sponsored by the Department of Energy. As mentioned, NIST is providing funding to support the construction of an industry scale facility at Georgia Tech for carbon capture research. Georgia Tech also manages the NIST Manufacturing Extension Partnership (MEP) for the State of Georgia. Additional sponsors include the National Institutes of Health, the Department of Homeland Security, and NASA. Collectively, the research conducted across the Georgia Tech enterprise compliments and benefits the portfolio of work sponsored by DoD organizations.

There is another important aspect of Georgia Tech's overall research sponsorship. It has enabled the support of a world class faculty that provides global thought leadership in many areas. The US no longer retains dominance in research. But faculty, coupled with a diverse international graduate student base, understand and leverage (and often lead) research on the global stage. Increasingly crowd sourcing methods are used to "cast the net wide" to foster a generation of innovative ideas and to engage a global research community to establish critical mass with which to attack a fundamental problem. This is an important means to leverage investment, to provide thought leadership, and to understand trends.

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[13] http://www.gatech.edu/research, http://www.gtri.gatech.edu/history/innovations
[14] https://www.sensiac.org
[15] http://www.falconview.org
[16] http://www.gtri.gatech.edu/news/fly-multidisciplinary-gtri-team-tackles-urgent-air
[17] http://spectrum.ieee.org/robotics/military-robots/autonomous-robots-in-the-fog-of-war/0
[18] http://www.nsf.gov/pubs/2000/nsf00137/start.htm

Example 3 – Lateral Transfer to Other Markets: Because the Bayh-Doyle Act allows universities to retain ownership of intellectual property generated under DOD sponsorship (for non-DoD applications), Georgia Tech is very active in supporting other commercial markets in areas such as biomedical devices and food processing. An excellent recent example is the spin-out company CardioMEMS,[19] a biomedical device company in Atlanta spawned from Army funded research for the development of a pressure sensor to be used in particular locations in an engine to provide control signals and thus ensure optimal engine performance. The government funding provided by the Army Research Office that was directed to the development of this sensor was approximately $500,000. The DoD need was for a small size sensor capable of operating in harsh environments, such as high temperature and with wireless interrogation capability. In 2000-2001, discussions with a medical doctor interested in exploiting microelectromechanical systems (MEMS) based manufacturing technologies to create a new generation of medical devices were held. Wireless sensors, that could detect disease states from within the body, were a particular interest. CardioMEMS licensed key patents originating from the Army funded research project exclusively in the field of medical devices. Based on these patents, CardioMEMS engineers developed wireless sensors as monitors of endovascularly- repaired abdominal aortic aneurysms. The sensors are integrated with an external measurement antenna. A real-time waveform of the pressure environment of the excluded aneurysm is extracted and provided to the physician to diagnose the state of the aneurysm repair. Nurtured in the incubators at Georgia Tech, today CardioMEMS resides in a building on the Georgia Tech campus devoted to private-public innovation and technology transition in the biotechnology space and to date has received approximately $50 million in private equity investment, a ratio of approximately $100 of private investment for each $1 of government investment. CardioMEMS currently employs over 100 people. Its wireless pressure sensors for aneurysm sensing were cleared for sale in the United States by the FDA in late 2005 and to date thousands of people have received them.

Benefits of Sponsored Research

The Georgia Tech research strategy and examples cited underscore seven benefits derived by the DoD.

1. **Breakthrough Research:** Discoveries related to advance materials **(**e.g. composites, graphene) systems analysis; sensors of phonon, electromagnetic and infrared, nanotechnology, control multiple autonomous vehicles, and in many other areas are examples of significant research results from defense sponsored research.

2. **Access to subject matter experts**: Georgia Tech has an outstanding faculty, including a large cadre of defense subject matter experts, who engage in fundamental research, direct problem solving, and transition activities that directly benefit DoD organizations and its industry base. This benefit is derived not only by DoD laboratories, but across the defense acquisition, training, test, and sustainment enterprise.

3. **Leveraged use of unique infrastructure:** Georgia Tech maintains unique facilities with costs shared by its entire sponsorship base and the State of Georgia (e.g., classified labs, information sharing services) designed to support and accelerate transition to the defense community and to other markets.

4. **Accelerated transition:** An aspect of the strategy and work described in this testimony include collaboration and partnering with the defense industry to accelerate the transition of research results into use.

[19] http://ww.cardiomems.com

5. **Amplified and leveraged funding:** Commercialization activities afforded by the Bayh-Doyle Act results in significant investment by the private sector to mature and apply technologies that can be required at less cost and at reduced time cycles by the DoD. A recent report from the Office of the Director of Defense Research and Engineering highlights this benefit.[20]

6. **Global engagement:** Faculty and graduate students participate in research on a global stage and thus understand trends. This "casting the net wide/crowd sourcing" is an important approach to bring innovation to research and to leverage funding.

7. **Educated workforce:** Lastly, Georgia Tech conducts research, transition, and commercialization activities to enhance its ability to provide a quality education to its undergraduate, graduate, and continuing education students. The next section briefly summarizes some unique educational offerings that directly benefit the DoD and which illustrate the use of innovation best practices.

Related Education Offerings

Beside its well-known, high quality traditional degree programs at the undergraduate and graduate level, Georgia Tech has introduced several innovative offerings to both meet the need of the defense sector and to bring innovation to experimental and problem-based learning across its educational enterprise. A brief summary of some of these offerings follow.

1. **Professional Master's Degree:**[21] A professional masters in applied systems engineering was introduced two years ago. It is taught by faculty in the College of Engineering and GTRI. It is offered in an executive education format and is tailored to the application interests of each cohort. To date, 11 class sections have been offered. The program has proven very popular and the investment cost for developing it was "paid back" in two years. Courses are offered at the main campus and Georgia Tech's 13 field offices throughout the United States. A distance learning version is being developed.

2. **Defense Electronics Program:**[22] Georgia Tech's continuing education department offers a well-known program tailored to the professional education needs of the defense sector. Currently, over 90 courses and 10 certificate programs are offered. The program is one of the largest of its kind in the country and is continually updated to reflect research results and needs of the defense sector. Significantly, the courses offered here, and through the before mentioned SENSIAC program, are taught by subject matter experts (i.e., the faculty engaged in underlying research and its application).

3. **The Contracting Academy at Georgia Tech:** To support nontraditional companies who want to provide services to the DoD, Georgia Tech established specialized training and consulting support two years ago.[23] The academy also provides continuing education opportunities for acquisition professionals located in the southeast. The Contracting Education Academy at Georgia Tech was recognized by the Defense Acquisition University (DAU) as an official equivalency provider of DAU course work.

4. **Competitive games in support of problem-based learning:** In addition, Georgia Tech is increasingly using competitive games, a proven means in industry to discover disruptive

[20] http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA526521&Location=U2&doc=GetTRDoc.pdf
[21] http://www.pmase.gatech.edu/program
[22] http://www.pe.gatech.edu/defense-technology
[23] http://contractingacademy.gatech.edu/2011/06/georgia-tech-now-offering-advanced-government-contract-training-in-atlanta/

innovation, as a means to support problem-based learning. Student teams, under the guidance of a faculty member (and often with an engineer from a sponsoring government or industry organization), seek a solution to a wicked problem in the span of a semester. This approach has been used for many years in the Aerospace Systems Design Lab (ASDL) in the School of Aerospace Engineering.[24] More recently, companies like General Electric have sponsored competitions to solve hard problems related to the smart grid.[25] Industry practices for support of disruptive innovation have cited the benefit of a neutral site for exploration and experimentation outside standard business units. Routine results, realized by Georgia Tech's industry sponsors are rapid generation of new IP and patent filings. Significantly, Georgia Tech has embraced this approach in its defense related work too. A team of engineers from Georgia Tech finished second in the well-publicized DARPA Red Balloon Challenge in 2009.[26] In addition. GTRI currently has three ongoing projects in support of the Navy and the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) applying competitive games with teams of students in areas spanning signal intelligence, autonomous systems, and space application. Sometime referred to as "DART" experiments,[27] these efforts provide outstanding experimental learning opportunities for students and provide a means for rapid assessment and discovery of innovative approaches for solving hard problems for sponsors. This work has been further developed into a Georgia Tech wide competition for entrepreneurs called InVenture Prize[28] and an accelerator for spinouts called Flashpoint.[29]

Georgia Tech Role in the Ongoing Public Discussion on Innovation

Public service and collaboration are core values of Georgia Tech. Georgia Tech has played an integral role in framing the public dialog on innovation policy and best practices. Its president, G.P. "Bud" Peterson, was selected by the Secretary of Commerce to serve on the National Advisory Council on Innovation and Entrepreneurship (NACIE), which has been charged by the Secretary to "identify and recommend ways we as a nation remain the source and home of paradigm changing innovations and the companies that deploy them." The four university presidents who are members of NACIE co-authored a letter to the Secretary of Commerce that was signed by 141 university presidents and pledges greater efforts to advance regional and national economic growth. Dr. Peterson was also appointed to the steering committee of the Advanced Manufacturing Partnership, a coalition of leading experts on advanced manufacturing from industry and academia brought together to chart a path toward deciding how our country should invest in the emerging technologies that will create high quality manufacturing jobs and enhance our global competitiveness. Georgia Tech has also hosted national and regional meetings on its campus on behalf of the Department of Commerce to develop recommendations from the private sector on how to enhance innovation and industry competiveness.[30] At the June 2010 event, the Secretary of Commerce commented on the thought leadership provided by Georgia Tech both through its research and economic development programs as well as its leadership at the national level in the ongoing public-private discussions about innovation and entrepreneurism. Other senior administrators and faculty have participated in advisory boards on similar topics (such as the testifiers own service in leading related studies for the DoD). These are just a few of the recent examples of how a major research university has taken a proactive approach toward our economic development work while trying to maximize impact.

[24] http://www.asdl.gatech.edu/
[25] http://site.ge-energy.com/about/press/en/2011_press/012011.htm
[26] http://www.gtri.gatech.edu/casestudy/red-balloon-darpa-challenge
[27] http://www.wired.com/dangerroom/2009/02/blue-dart/
[28] https://inventureprize.gatech.edu/
[29] http://flashpoint.gatech.edu/
[30] http://www.commerce.gov/news/secretary-speeches/2010/07/15/remarks-department-commerce-university-innovation-forum-georgia-i

Innovation in Defense Research Now Paramount

At a time of potential budget cuts for defense research, there are significant lessons learned from history during times of unprecedented change. A "think piece" – a national strategic narrative[31] – was written by two forward looking officers serving under Admiral Mike Mullen, who recently retired as the Chairman of the Joint Chiefs of Staff. The document calls upon America to observe that we are living in a period of rapid change in all aspects of our lives and that our country will face new threats in the future. The document explores classes of threats we will face that are unprecedented and not related to a Cold War philosophy which still dominates much of our national security policy. We no longer have the luxury of waiting to be surprised by the use of new technologies against us. Only through research and coupled programs in technology transition and innovation can we hope to retain a competitive edge. That is, we must be creative in how we shorten the time between understanding a future threat and responding with a suitable response. One only need look at a few past military examples where innovation was not embraced, even though results from defense research had matured to the point of commercial application. A fascinating book entitled *Military Adaptation in War*[32] by Williamson Murray recounts numerous examples from military history where fundamental change and applicable innovations have been ignored. Murray goes on to state that those military organizations that can best adapt to the "fog of war" are those that embrace innovation during peace. A culture of experimentation and competition involving research organizations and the rest of the defense enterprise (e.g., war fighters, acquirers, trainers, testers, sustainers) is critical. Innovation practices for inculcating such in organizations have been codified.[33] Initiatives such as the Chief of Staff of the U.S. Army's Strategic Studies Group are commendable and should be encouraged. Venues outside of traditional organizational units have proven useful for fostering such exploration. Research universities, such as Georgia Tech, are well poised to provide this kind of support.

Summary

In summary, defense research and associated technology transition and innovation programs are vital for ensuring the United States retains a competitive advantage in its national security posture. As shown time and time again, the fruits of defense research seed economic development, helping to accelerate new technologies to market; those technologies are available for use in defense systems at a fraction of what they would otherwise cost (and at much reduced time scales). There have been many instances in the past where we have missed a fundamental change or ignored the potential of a new innovation, but our country has relied on time and distance from adversaries in order to rebound. As the world has continued to shrink and the quality of global research has improved, our country must respond faster and more effectively. Lessons learned from innovation have been codified into best practices and can be applied to ensure continued relevancy of defense research and to facilitate faster maturation and transition to use. Significantly, such practices also provide new insight and understandings into the challenges our country will face in the future and thus provide insight and guidance for enabling research.

Thank you for this opportunity to provide testimony to this important panel. I look forward to your questions.

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[31] http://www.facebook.com/pages/A-National-Strategic-Narrative/220785844603507, http://www.nytimes.com/2011/05/04/nyregion/a-strategy-for-national-security-focused-on-sustainability.html

[32] http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA509781

[33] http://www.au.af.mil/au/awc/awcgate/sab/sys_level_experimentation_report.pdf