Summary of the testimony of

James M. Tour, Ph.D.

Before the

House Energy and Commerce Subcommittee on Commerce, Manufacturing and Trade

"Nanotechnology: Understanding How Small Solutions Drive Big Innovation"

July 29, 2014

There are three topics relevant to my testimony today:

1. The research enterprise in universities;
2. Industries and their need to recruit top personnel in science and technology; and,
3. Stemming the tide of the brain drain, wherein we are losing our best and brightest to overseas institutions.

The decrease in federal support for university-based basic research in recent years is resulting in a serious brain drain that imperils the future of the U.S. economy as we know it. International graduate students are returning to their home countries in Europe and Asia to do research. The serious lack of research funding has lead to a lack of new academic positions for young researchers and has made top faculty susceptible to be lured overseas.

This situation can slowed and perhaps even halted without commitment of <u>any new monies</u>. Congress must properly incentivize industry to invest in university research. Expanding tax deductions to companies who enter into sponsored research agreements with universities will spur investment and encourage faculty to be more entrepreneurial while underwriting the basic research needed to help America retain her competitive edge.

NANOTECHNOLOGY: UNDERSTANDING HOW SMALL SOLUTIONS DRIVE BIG INNOVATION

Testimony before the Subcommittee on Commerce, Manufacturing and Trade

Committee on Energy and Commerce, United States House of Representatives

July 29, 2014

James M. Tour, Ph.D.

Richard E. Smalley Institute for Nanoscale Science and Technology

Rice University

Chairman Terry, Vice Chairman Lance, Ranking Member Schakowsky and other committee members, I appreciate the opportunity to testify before the subcommittee. I am the T.T and W.F. Chao Professor of Chemistry, Professor of Computer Science and Professor of Materials Science and NanoEngineering in the Richard E. Smalley Institute for Nanoscale Science and Technology at Rice University in Houston, Texas.

Rice University is considered the birthplace of nanotechnology and is a leader in the field of finding pathways to commercialization of this promising technology. Rice is the location where C60, known as Buckminsterfullerene or the "buckyball", was discovered in 1985 by Richard Smalley, Robert Curl, Harold Kroto, and their team of students. That discovery, more than any other single discovery, is credited with the genesis of nanotechnology, and that single discovery led to three Nobel Prizes in Chemistry. Rice is now one of the premier research facilities in the world that supports and promotes researchers who use nanotechnology to tackle civilization's grand challenges – energy, water, environment, disease, education – by providing experienced and knowledgeable leadership, a solid administrative framework, world-class scientific infrastructure, and productive community, industry, and government relations. To demonstrate the tremendous depth of nanotechnology research at Rice, I have provided an extensive list of the major nanotechnology breakthroughs that occurred on our campus in Appendix 1.

I personally have over 500 research publications and 70 patents in nanotechnology including:

(1) nanomedicine for treatment of traumatic brain injury (the number one disabler of young adults), stroke (the number one disabler of older adults), and autoimmune diseases;
(2) nanomaterials including graphene and carbon nanotubes for electronics, optics and composites;
(3) nanoelectronic memories set to rival flash memory; and,

(4) high-surface-area nanomaterials for environmental capture of carbon dioxide from natural gas wells and radioactive element removal from water for clean-up of mining waters, oil extraction waters, and nuclear legacy site waters.

All of these are licensed technologies to companies from my Rice laboratory and all have transitioned from the basic research phase to deployment in the US and abroad.

There are three topics relevant to my testimony today:

1. The research enterprise in universities;
2. Industries and their need to recruit top personnel in science and technology; and,
3. Stemming the tide of the brain drain, wherein we are losing our best and brightest to overseas institutions.

Congress can directly impact these three situations, and this can be done without commitment of <u>any new monies</u>.

Among the most ingenious pieces of legislation, in my view, impacting university-based research was the Bayh–Dole Act dealing with intellectual property arising from federal government-funded research. Before Bayh-Dole was enacted, the U.S. government had licensed fewer than 5 percent of the 28,000 patents it has accumulated.[i] Bayh-Dole changed the ownership of inventions, which had been assigned to the federal government, resulting from federal grants.[ii] Under Bayh-Dole, universities, small businesses, and non-profits have preference in pursuing ownership of an invention.[iii] Government got out of the way, and this spawned enormous entrepreneurial endeavors that led to start-up companies and jobs being birthed throughout the

country, like those in Silicon Valley. And most interestingly, the legislation required no new allocation of funds.

Unfortunately, there has been a dramatic loss of research funding to U.S. universities, on a per investigator basis, since the outpouring of the stimulus funds in 2009. The situation has become untenable. Not only are our best and brightest international students returning to their home countries upon graduation, taking our advanced technology expertise with them, but our top professors also are moving abroad in order to keep their programs funded. For the past century or more, the U.S. has been the recipient of the world's most talented students, profiting from the brain drain of other nations.

In 2011, I testified before the House Science, Space and Technology Subcommittee on Research and Science Education that if the funding of U.S. research did not increase, the United States would experience a brain drain like we have never known. Unfortunately, my projections have come true: we are presently in the throes a brain drain that should be frightening to everyone. My best students are returning to Asia and Europe to embark on research careers solely because there are so few academic positions available for them in the United States due the lack of federal research support. Equally alarming is the loss of key US-based nanotechnology faculty to the U.K., South Korea, China, Singapore and Australia. This is not from any specific government report; this is based upon my own knowledge of the field. I formerly testified that university researchers are industrious folks, and the most astute among them would rather move abroad than to see their prized research programs close. This is now happening. And the trolling by foreign universities upon top U.S. faculty has become rampant due to the decline of federal

funding levels on a per faculty-member basis. This brain drain is not something that we can recover-- the impact of what has already been lost will last decades. .

As university research programs shrink substantially or close down, there will be a diminishing supply of US-trained and US-national scientists and engineers. Certainly the United States can hire from abroad, but that is not so easy for some industries, such as in the aerospace sector. Moreover, the cutting-edge of our nation's leading enterprises will be dulled into disrepair. The lack of highly trained scientists and engineers is already felt, but it will grow far worse. I am not here to present you with an apocalyptic scene and then cry for money to slow the problem. I realize that the cupboards in Washington are bare. Instead, I offer you a no-new-monies solution. I shall share with you the secret and then show you what your committee can do to make this an easier transition for many research groups around the country.

I have a large research laboratory: 30 graduate students and post-docs working busily to make new nanotechnology discoveries and translate those into exploitable applications. My research funding situation is as good as it has ever been. In 2008, my program was 90% federally supported and 10% industry supported. That was the norm for many research groups. Then, for the first time in my 26-year career as a faculty researcher, I could no longer survive. One federal grant after another was unfunded. Federal programs would attract 300 initial applicants, 150 full proposals, and then only have enough to fund 5 research groups. Federal organizations would post programs for proposal submissions. I would submit a proposal, only to learn that they would shut down the program without even reviewing a single proposal. There was no recognition of the time I already spent in writing proposals – it felt humiliating and disrespectful.

I started to appeal to industry, showing them how our nanotechnology research could address the technical needs in their industries. I have the good fortune of being in Houston where oil companies are headquartered, and the energy industry is doing well. But this has now expanded to companies far beyond Houston. We do basic research in nanoscience, and then parlay that into applied nanotechnology research that can benefit companies. More than 15 companies have stepped up to fund my research.

If a company gives a monetary gift to a university, the company can get a healthy tax deduction. However, industry cannot request a report on the outcome of gift-supported research, meaning companies are less likely to give gifts. There is little accountability in providing gifts, so few companies choose this route. If the company grants money though a sponsored research agreement, they can require reports of the work and even request milestones. These sponsored research agreements are indirect-cost bearing, so they maintain the academic laboratory infrastructure. According to Bayh-Dole, the intellectual property still resides with the university, but the university can license, even exclusively, to the company sponsoring the work. While the intellectual property cannot be "pipelined," meaning that it cannot be assigned to the company prior to its being generated, a letter of intent to license to the company is sufficient to give the company assurance that it could be the recipient of the funded work. And per Bayh-Dole, the government receives a "nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world."[iv] Such restrictions have never bothered a U.S. company with which I have dealt.

Here is where Congress can help. If the company funds research at an academic institution through a sponsored research agreement, thereby guaranteeing the company access to research

reports and their setting of milestones, then the company loses the benefits of a significant tax deduction through their allocation of funds. I ask Congress to consider legislation that would incentivize industry to fund academic research universities and non-profits by granting companies with a total or significant taxable deduction university research investment. This permits companies to take up the slack where the federal government has been failing to maintain the research enterprise. Such a program will slow the brain drain, possibly even mitigate it, and provide for the high tech training of students that will be needed to fill jobs in those industrial sectors. It will further encourage faculty to be more entrepreneurial in their raising of funds for research.

The complexity associated with industry grants to universities needs to be streamlined and incentivized. There is no simple answer as to how much a company can presently deduct, if anything, on a sponsored research agreement. Even when I consulted with industry tax experts they provided no easy answers. This is an issue for Congress to explore further, working with industry, tax experts, and universities to design an effective incentive structure that will increase industry support for research and development – especially as it relates to nanotechnology. This is a win-win for all parties: more university research getting funded, slowing the brain drain, and providing a substitute for federal research support.

Such a strategy can help me and my colleagues to raise our own research funds through partnerships with corporations. If I can explain to industries that there will be a complete or significant tax deduction for the sponsored research agreement, then I can sell my research to them with the utmost attractiveness.

Some researchers might argue that basic research will suffer at the expense of applied research. Not so. I always tell industries that their investment will be used, in part, to expand upon the basic research scope while still delivering upon the applications. We file patents regularly to secure the intellectual property, and then we publish as usual in the academic literature. The protocol works.

In closing, I ask your kind consideration for new, Bayh-Dole-like legislation to be enacted to mollify the dire conditions facing the U.S. research enterprise: legislation that would require no new monies while incentivizing industry to fund research where the federal government has been deficient.

Appendix 1: Nano Breakthroughs at Rice

Bio/Health Science

Finding and Killing Cancer:

- **Nanoscale composites improve MRI: Rice, Methodist researchers merge magnetic particles to detect, fight disease.** ***(Wilson, Gizzatov, 6/13/14)***
- **Short nanotubes target pancreatic cancer: Rice, MD Anderson scientists refine technique for attacking hard-to-reach tumors.** ***(Barron, 6/5/14)***
- **'Quadrapeutics' works in preclinical study of hard-to-treat tumors: Animal tests show Rice-developed technology effective against aggressive cancer.** ***(Lapotko, Lukianova-Hleb, 6/1/14)***
- **Bismuth-carrying nanotubes show promise for CT scans: Rice-led collaboration finds element shines as contrast agent for tracking stem cells.** ***(Wilson, 9/4/13)***
- **3-D scaffolds a new tool to fight cancer: Rice University and MD Anderson researchers see more realistic tumor growth and response to anti-cancer drugs using polymer scaffolds .** ***(Mikos, 4/1/13)***

Healing Babies, Soldiers and Accident Victims:

- **A hydrogel that knows when to go: Rice University bioscaffold material degrades as bone grows to replace it.** ***(Mikos, Watson, 5/7/14)***
- **Synthetic collagen promotes natural clotting: Hydrogel invented at Rice University may help 'nuanced' healing of surgical wounds.** ***(Hartgerink, 4/9/14)***

- **Tiffany Vo wins Ruth L. Kirschstein National Research Service Award: Research uses dual-gelling, temperature-sensitive scaffolds to engineer bone.** ***(Vo, 11/27/13)***

- **Grant to Rice, UTHealth will push regenerative medicine: Department of Defense backs tissue-engineering research for soldiers, civilians.** ***(Mikos, 9/27/13)***

- **Jacot's TEDx talk posted online: assistant professor of bioengineering discusses the use of stem cell-derived tissue, plus synthetic materials, to repair infant hearts.** ***(Jacot, 7/29/13)***

Keeping People Safe from Bad Food and Other Diseases

- **New test targets salmonella: Rice University-based research develops fast biosensor for pathogens in food.** ***(Biswal, et al., 1/21/14)***

- **Vapor nanobubbles rapidly detect malaria through the skin: Transdermal malaria technology successfully completes first preclinical tests at Rice.** ***(Lapotko, Hleb, 1/1/14)***

- **New clues illuminate Alzheimer's roots: Rice, Miami researchers find binding sites in amyloid fibrils that may lead to therapies.** ***(Marti, 7/19/13)***

- **Rice's Laura Segatori wins NSF CAREER award: Engineering researcher creating new nanoscale tools to study Parkinson's disease.** ***(Segatori, 3/28/13)***

- **Heart cells beat in bioscaffold for babies: Rice, Texas Children's team creates biocompatible patch to heal infants with birth defects.** ***(Jacot/Park, 12/12/12)***

- **Smart scaffolding aims to rebuild tissue from the inside: what's new is injecting scaffolds infused with living cells, to facilitate repairs inside the tissue's natural environment. *(Hartgerink, 11/12/12)***

Energy and Environment

- **Water-cleanup catalysts tackle biomass upgrading: Rice University researchers using catalysts to convert waste from biodiesel production into valuable chemicals. *(Wong, 6/26/14)***
- **Rice's Thomann wins CAREER grant to study photocatalysis: Rice lab's unique spectrometer will shed light on solar-powered CO2 reduction. *(Thomann, 6/19/14)***
- **Rice produces carbon-capture breakthrough: Porous material makes it feasible to do CO2 capture at natural gas wellheads. *(Tour, Hwang, 6/3/14)***
- **Nanoreporters tell 'sour' oil from 'sweet': Rice University's hydrogen sulfide nanoreporters gather intel on oil before pumping. *(Tour, Wong, Tomson, Marti, 4/18/14)***
- **Nanoparticles show fluid flow in wells: can test safety of frack fluids, frack jobs and other Oil & Gas production. *(Barron, Boyle, 2/24/24)***
- **Rice startup Rebellion Photonics wins Wall Street Journal Startup of the Year competition, 2013. *(Allumni Kester and Sawyer; faculty Tomasz Tkaczyk, 11/6/13.)***
- **Using foam to get more oil & gas out of the ground: may prove big advantage over tradictional water or CO2 flooding for enhanced oil recovery. *(Biswal, 10/7/13)***
- **Off-grid sterilization with Rice U.'s 'solar steam': solar-powered sterilization technology supported by Gates Foundation. *(Halas, Neumann, 7/22/13)***

- **Chloroform cleanup: Just the beginning for palladium-gold catalysts: Federally funded research pays off with new process for environmental remediation. *(Wong, 4/15/13)***

Batteries and Solar Energy

- **One step to solar-cell efficiency: Rice University researchers' chemical process may improve solar cell efficiency and manufacturing via etched nanospikes. *(Barron, 6/19/14)***
- **Flexible battery, no lithium required: Rice University lab creates thin-film battery for portable, wearable electronics. *(Tour, Yang, 4/25/14)***
- **Clay key to high-temperature supercapacitors: Rice University lab creates energy storage that may find use in oil discovery, space, military applications. *(Ajayan, Reddy, 9/3/13)***
- **Rice cultivates green batteries from plant: extract of madder plant works as environmentally friendly lithium-ion cathode. *(Ajayan/Reddy, 12/11/12)***
- **James' bond: A graphene/nanotube hybrid: Rice University's James Tour Group creates single-surface material for energy storage, electronics. *(Tour, 11/27/12)***
- **Rice unveils super-efficient solar-energy technology: 'Solar steam' so effective it can make steam from icy cold water. *(Halas, 11/19/12)***
- **Toughened silicon sponges may make tenacious batteries: Rice, Lockheed Martin researchers extract multiple anodes from a single wafer for lithium-ion batteries. *(Biswal, 7/16/12)***

- **Paintable battery: uses carbon nanotechnology to enable layers to be cathode, anode, etc. *(Ajayan, 6/28/12)***

Electrical, Electronics

- **Rice's silicon oxide memories catch manufacturers' eye: Use of porous silicon oxide reduces forming voltage, improves manufacturability. *(Tour, 7/10/14)***
- **Silicon oxide memories transcend a hurdle: Embedded diodes boost Rice University invention's potential as robust, roomy memory. *(Tour, 7/9/13)***
- **2-D electronics take a step forward: Rice, Oak Ridge labs make semiconducting films for atom-thick circuits. *(Ajayan, Lou, Liu, Yakobson, 6/10/13)***
- **Totally tubular films show promise for touchscreens: Rice University lab creates simple method for flexible, conductive carbon nanotube sheets. *(Pasquali, 10/29/12)***
- **Thanks for the transparent memories: Rice team progresses in quest for reliable, flexible computer memory. *(Tour, 10/2/12)***

Materials: Structure, Multifunction

- **3-D nanostructure could benefit nanoelectronics, gas storage: Rice researchers predict functional advantages of 3-D boron nitride. *(Shahsavari, 7/15/14)***
- **Rebar strengthens case for grapheneRice University lab makes hybrid nanotube-graphene material that promises to simplify manufacturing. *(Tour, 4/4/14)***
- **Diamonds are an oil's best friend: Rice University leads research to find the best nanofluid for heat transfer. *(Ajayan, 3/27/14)***

- **Graphene nanoribbons an ice-melting coat for radar: Rice University discovery is cheaper, lighter and more effective than current deicers. *(Tour, Volman, Zhu, 12/13/13)***

- **Carbon's new champion: Rice U. theorists calculate atom-thick carbyne chains may be strongest material ever. *(Yakobson, 10/9/13)***

- **'White graphene' halts rust in high temps: Rice U. researchers find nano-thin films of hexagonal boron nitride protect materials from oxidizing. *(Ajayan, Lou, 10/4/13)***

- **New nanotech fiber: Robust handling, shocking performance. Nanotube fibers have unmatched combination of strength, conductivity, flexibility. *(Pasquali, 1/10/13)***

- **Microbullets reveal material strengths: Rice, MIT research could help maximize strength of body armor for soldiers, aerospace materials. *(Thomas, 10/30/12)***

- **Strain Paint: uses carbon nanotubes to detect strain in real time. *(Nagarajaiah, Weisman, 6/21/12)***

Photonics, Opto-Electronics

- **Rice nanophotonics experts create powerful molecular sensor: Sensor amplifies optical signature of single molecules about 100 billion times. *(Halas, LANP, 7/14/14)***

- **San Marcos tech company bets big on tiny quantum dots [Austin American-Statesman]: Quantum Materials licenses Prof. Mike Wong's tetrapod technologies from Rice; attracts interest from Sony and others. *(Wong, 11/16/13)***

[i] http://www.gao.gov/archive/1998/rc98126.pdf
[ii] http://www.bu.edu/otd/files/2011/02/The-Enactment-of-Bayh-Dole.pdf

[iii] http://www.natlawreview.com/article/emerging-energy-and-intellectual-property-often-unappreciated-risks-and-hurdles-gove

[iv] 35 USC Sec 202 (c) (4) of the Bayh-Dole Act