Nanotechnology: Oversight of the National Nanotechnology Initiative and Priorities for the Future

Testimony of
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Chairman Brooks, Ranking Member Lipinski and Members of the Subcommittee on Research and Science Education; I appreciate the opportunity to testify before you today on three aspects of nanotechnology of great importance to the nation, Rice University and myself. My name is James Tour. I am the T.T and W.F. Chao Professor of Chemistry, Professor of Computer Science and Professor of Mechanical Engineering and Materials Science in the Richard E. Smalley Institute for Nanoscale Science and Technology at Rice University in Houston, Texas. I have over 400 research publications and 50 patents on nanotechnology topics ranging from high performance materials, ultra-small electronic devices, targeted cancer delivery agents, and nanomachines.

I come before you today to address three critical concerns:

1. Foreign competition,
2. Federal funding beyond the discovery phase, and
3. Paths to commercialization.

Overview of the Smalley Institute

Rice University is the location where C60, known as Buckminsterfullerene, was discovered in 1985 by Richard Smalley, Robert Curl and 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. The Smalley Institute at Rice University 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. Rice University owns more licensed nanotechnology patents than any other university in the world.

The Smalley Institute interacts with the private sector at several levels. We interact with major corporations (such as Lockheed Martin Co.) directly at a high level by forming centers (such as the Lockheed Advanced Nanotechnology Center of Excellence at Rice, or LANCER) to perform basic research in multiple projects which address significant technical challenges faced by the corporate scientists and engineers. LANCER, now in its fourth year, has funded six initial projects, at an overall level of funding of

about $1.5 million per year. The Rice/Lockheed partnership has resulted in over 200 Lockheed engineers and scientists being trained at Rice during week-long courses on nanotechnology. The Smalley Institute is currently working on two or three additional corporate relationships that have the potential to reach the same funding and partnership level as LANCER.

The Advanced Energy Consortium (AEC) is a second example of corporate funding that the Smalley Institute helps to foster, independent of any government support. The Smalley Institute and the University of Texas at Austin started the AEC, joining ten major oil and gas companies together at a level of funding of $10 million per year, starting in January 2008. Rice has benefitted from AEC funding at about $2 million year for direct research projects to explore the use of nanotechnology down hole in characterizing oil and gas formations and increasing production from those fields.

In addition to the above examples, the Smalley Institute assists in connecting individual companies with individual Rice researchers to perform sponsored research projects .These projects range from a few thousand to $500,000, and cover a wide range of nanotechnology fields.

In the area of philanthropic funding, the Smalley Institute also serves as the advocate for fund-raising from both individuals and foundations to support Rice's infrastructure of research as well as direct funding of research, especially in terms of undergraduate, graduate student, and postdoctoral fellow funding, both immediate use and endowed funds. We have raised funds to build buildings (Dell Butcher Hall, the first dedicated nanotechnology building in the world that was completed in 1997), help hire and endow talented new faculty members, buy research equipment, support meetings and workshops and seminars, and encourage nanotechnology education. We also provide local, national and international outreach activities to advance nanotechnology through lectures, short courses, and even classes in our continuing studies department.

Key Nanotechnology Issues

As our country struggles to emerge from the recession, the most important issue to the public is jobs. Nanotechnology is an enabling technology that, if supported and developed adequately, will usher in the next industrial revolution and create hundreds of thousands of new jobs and make products that are more competitive globally. According to a presentation by Clayton Teague, Director of the federal National Nanotechnology Initiative, the nanotechnology industry currently employees over 150,000 Americans and that number is expected to grow significantly. It is estimated that there could be as many as 800,000 direct jobs in nanotechnology by 2015. That is less than four years from today. These are highly skilled, highly paid jobs that result in long-term sustainable economic development for the countries that support them. As the Internet revolution propelled our economy in the early 90's, nanotechnology can be the major driver of economic growth over the next two decades. The U.S. needs to make important decisions now to ensure that this growth occurs in the United States where it can be of greatest benefit to U.S. citizens who provided the resources to fund this technology.

When we talk about nanotechnology, we are not talking about something in the future, but something that exists today. Nanotechnology is used now in electronics, energy, medicine, cosmetics and

materials. At Rice University, we incorporate carbon nanomaterials into high-strength composites that produce lighter and more conductive materials that can be used as lightweight body armor for our troops or in electrical wiring. We inject gold nanoparticles directly into the bloodstream of patients to target and kill cancer cells. Carbon nanoparticles are also being used to make printable radio frequency tags that will displace barcodes and permit real-time inventory in warehouses. Nanofilament-based silicon will also usher in the post-flash electronic memories that will drive handheld communication and entertainment devices used today. Graphene, single-atom-thick sheets of carbon grown from table sugar and a nanotechnology application can be used for touch-screen displays on, for example, cell phones. This would allow the entire phone to be rolled up like a pencil to insert in your pocket. These are not technologies expected in the future. These technologies are being used today and U.S. workers, the same ones whose taxes paid for the technology development, can manufacture and produce these products if the U.S. government continues to support and fund nanotechnology research and commercialization at an adequate level. My personal life story testifies to the positive impact of federal funding for education, research and commercialization of technology. I am the child of immigrants who came to the U.S. seeking a better life and, as we worked for it, we found it. My Ph.D. and laboratory research was subsidized by federal research grants. While I am thankful for a government that has created opportunity for me and many others to make world-changing and life-saving discoveries, I am gratified that these discoveries also create a demand for high quality education, produce high-paying jobs, attract global talent, revolutionize manufacturing and solve difficult problems. All of these benefits to the U.S. will be lost if we fail to address the following three issues:

1. Foreign competition,
2. Federal funding beyond the discovery phase, and
3. Paths to commercialization.

Foreign Competition

Foreign governments compete for nanotechnology human talent, research and manufacturing because these things are the key to global competitiveness. The primary areas of competition are:

- Basic research discoveries that lead to scientific papers and then to Intellectual Property, such as patents,
- Hiring and funding of nanotechnology researchers, and
- Commercializing and investing in nanotechnology enterprises.

The U.S. leadership role in each of these areas is threatened because other countries are aggressively implementing national strategies to acquire this technological advantage and then compete against us.

The US is currently the intellectual leader for nanotechnology – representing close to 30 percent of all patents held and 23 percent of all scientific papers published internationally. In addition, the US government is also the largest investor in nanotechnology, investing close to $5.7 billion in 2008. However, other nations are beginning to close the gap. According to the March 2010 P-CAST report, from 2003 to 2008, U.S. public and private investments in nanotechnology grew at 18 percent annually,

while global investment grew at 27 percent annually. In addition, U.S. government investments in nanotechnology R&D were overtaken by European Union in 2005 and by Asia in 2008 (primarily Japan, China and South Korea). In fact, the executive summary of the P-CAST warns:

> "..the United States stands to surrender its global lead in nanotechnology if it does not address some pressing needs. Key among those is a need to increase investments in product commercialization and technology transfer to help ensure that new nanotech methods and products make it to the marketplace, and the need to strengthen [National Nanotechnology Initiative] commitments to explore in a more orderly fashion environmental, health, and safety issues."

Foreign interests will continue to invest in both the basic science and application of nanotechnology. Now is not the time for the U.S. to surrender its leadership position just as the results of our research investments are moving to commercialization.

Federal Funding Beyond the Discovery Phase

In order to preserve our leadership role, we must support federal nanotechnology funding beyond the discovery phase. Federal funding of basic research must continue because many companies are no longer conducting basic research. In order to continue this basic research, we must pay students because we have to pay them—they do not line up outside science and engineering departments as they do for medical and law schools. This federal support for scientists and engineers has a successful track record over the past 50 years as evidenced by the U.S. superiority in the Cold War, agricultural advances, energy development in the ultra deepwater and in shales and the space program to name just a few achievements.

It is an exciting time for nanotechnology because we are now moving from the initial discovery stage to corporate development labs, nanomanufacturing and emerging markets. This is the stage in technology development when the U.S. can begin to realize a return on our nanotechnology investment if we continue to support and fund nanotechnology research and commercialization at an adequate level. The Federal Government has a specific role in two major areas of nanotechnology: nano-manufacturing and the environment.

The key to a successful shift to commercialization of nanotechnology is through nano-manufacturing. Nano-manufacturing takes the basic science of nanotechnology and uses it in the production of nanoscaled materials. If we do not adopt and deploy an aggressive strategy to encourage the growth of nano-manufacturing immediately, we will find ourselves losers to China, India, Russia, Singapore and other places where government funds and supports the use nano-manufacturing to create jobs and wealth. As the U.S. manufacturing sector continue to shed jobs and as these jobs move abroad, nano-manufacturing is one bright spot of opportunity where the U.S. has the potential to be a world class global competitor.

In the past 18 months, I have been invited to Singapore once with a second trip planned this summer (both business class flights). I have had more than a dozen visits from Singaporean representatives, including two visits from their Economic Development Board. The purpose of these visits was to encourage me to do my work in Singapore. I have been promised a lab and funding to do my work there. In addition, I have been promised capital backing and a lower tax burden than the U.S. if I launch new nanotechnology companies there. I have also been approached by Russian, Chinese and Japanese representatives. In the past two weeks alone, officers from both Toshiba and Mitsubishi have been in my office. This is global competition and it is the realm in which we nanotechnology researchers work. I do not say this to add a threatening tone to this testimony. Rather, I share this information to provide some context in which to view my recommendations. American researchers are industrious and self-driven. If they cannot get our science funded and transitioned here, they will go abroad. And top researchers will not wait a decade for recovery. The brain-drain has already begun, and it will continue at an enormous pace within the next 1-3 years if access to research and development funds are reduced. Progress will continue, and it is my hope that the US will be the beneficiary of that progress. If American researchers start going abroad, the impact of the brain-drain would be devastating to near and long-term economic development in the US.

Environmental stewardship is also an area where the Federal Government needs to play a role in the post-discovery phase of nanotechnology development. Uniform and transparent environmental regulations are critical to the future growth of this industry. The government needs to encourage commercialization with sound science-based environmental stewardship, without creating unnecessary regulatory hurdles that are not supported by sound science. Nothing can stifle economic growth faster than regulatory uncertainty. Universities and companies need a framework to address this uncertainty. Without it, , we will struggle through this next stage. The NNI helps to provide this guidance across the 25 different agencies that touch nanotechnology. As nano-manufacturing develops rapidly worldwide, there is a need for a reasonable regulatory framework that protects human health and the environment.

The Federal Government has been a crucial partner in the discovery of nanotechnology. We must now use the nanotechnology tools funded by U.S. citizens to provide U.S. jobs and make U.S. products more competitive in the global market. This can be done through federal support for the commercialization of nanotechnology through support to universities and the private sector to move these technologies to the market and to the consumer.

Paths to Commercialization

Federal funding for nanotechnology beyond the discovery phase is needed to spawn the transitions from the laboratory to the manufacturing stage. This can be done through Private-Public partnerships where a competitive grants process keeps the government from choosing its favorites, and permits competition through grants applications analogous to the competitive Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs that merge universities with small companies for the transition from research to development and manufacturing.

We only need to look at Texas for a few examples of some successful efforts in business -government nanotechnology partnerships. One company that I founded is NanoComposites Inc. NanoComposites make tougher elastomeric materials using carbon nanotube composites for items such as oil-well blowout preventors that are eight times tougher than existing systems. The development was funded, in part, through the Emerging Technologies Fund (ETF) of the State of Texas. That funding saw the Company though a period of transitional research where the application of the basic science to real systems was too risky to be considered for private sponsorship. Now, a major oil service support company has seen the efficacy of the process and invested heavily in NanoComposites. This is an example of a Private-Public partnership. Outside of the ETF, the State of Texas also helps fund cutting edge research through the Cancer Prevention and Research Institute (CPRIT). CPRIT began with $3 billion in bonds to fund groundbreaking cancer research and prevention programs and services in Texas. CPRIT's goal is to expedite innovation and commercialization in the area of cancer research and to enhance access to evidence-based prevention programs and services throughout the State. This is a model that is working successfully in Texas and something the Federal Government should review to build upon its success.

Federal and state competitive funding for nanotechnology research has been wildly successful. We attract the best researchers in the world to our universities and these researchers, their institutions, and US companies hold the largest number of nano patents in the world. We are now equipped as a country to deploy these technologies to make our businesses more competitive globally. However, continued federal funding in the post discovery phase is necessary to capture the value of what we have achieved thus far. If we reduce funding and commitment to nanotechnology during this critical juncture, this decision would be the equivalent of dropping out of a race voluntarily when you are in first place.

The Way Forward

In order to achieve these goals, the National Nanotechnology Initiative (NNI) should be reauthorized to help guide the industry through transition. Currently, the NNI budget supports nanoscale science, engineering, and technology research and development (R&D) at 15 agencies with 10 additional participating agencies. NNI helps to align these agencies so that they can work in a coordinated way to move this technology from discovery to commercialization. A new reauthorization will allow the Federal Government, universities, and the private sector to work to find creative ways to bring these promising technologies to the market more quickly and economically. In the absence of reauthorization, these agencies will be focused in different directions and the industry will struggle to transition into the next stage while other countries continue to close the existing gap.

Conclusion

As Congress and the country wrestles with ways to encourage job growth in a global economy, nanotechnology is moving from basic discovery to commercialization. It is in this transition that we can begin to realize significant economic development and job creation. Our country is no longer the manufacturing leader in the world – we now outsource most of our manufacturing jobs overseas - but

this does not have to be the case with nanotechnology. The US is currently the intellectual leader in this promising field of discovery, but if we fail to make the investments needed today, then other countries will and we will begin to see the outsourcing of nano-manufacturing jobs overseas. Our government has made significant investments into this promising technology and now is not the time to walk away or diminish our financial commitment. I know that during these times of tight budget priorities must be made with funding. We have the opportunity to reclaim our manufacturing base that helped to build this great country. There is too much at stake to do nothing and other countries are already closing the gap. The issue before you is about economic development and a commitment to ensure that the United States remains the intellectual leader, driver and recipient of the economic benefits of this growing technology I close with the three priorities I urge the Subcommittee to address:

1. Foreign competition,
2. Federal funding beyond the discovery phase, and
3. Paths to Commercialization.

Thank you for your time. I would be honored to answer your questions.