Written Testimony of
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Nanotechnology: From Laboratories to Commercial Products

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Chairman Bucshon, Ranking Member Lipinski, and honorable members of the Subcommittee, my name is Leslie T. Ivie, and I am President and CEO of F Cubed, LLC, a company engaged in the commercialization of molecular detection technology for the rapid identification of pathogenic bacteria in medical diagnostic, food safety, and environmental science applications. Thank you for the opportunity to discuss nanotechnology. In my testimony I will describe:

- The ways in which companies such as F Cubed, LLC have benefitted from Federal funding in nanotechnology research.
- The importance of science, technology, engineering and mathematics (STEM) education in the development of the nanotechnology workforce and the ways in which F Cubed, LLC, is working to address the relevant STEM education and workforce needs associated with nanotechnology research and development and the manufacture of nanotechnology enabled products.
- The time, expense and complexity of the technology transfer process are significant barriers to nanotechnology commercialization and market success.
- Current and future Federal regulation of nanotechnology and the possible impacts on F Cubed, LLC and other participants in the industry.

A brief summary of the key points covered in my testimony is provided at the end of this document.

My testimony today is informed by my experiences as an executive with several international corporations, as well as my background as the founder of three start-up companies in the US and Europe. At the present time, US academic institutions and companies are the unquestioned world leaders in the field of nanotechnology. We operate in an economic environment that rewards innovation and we have access to human and financial resources that allow the development of highly differentiated and innovative technologies. Our ability to maintain or increase this lead requires the assurance of funding for the institutions that cultivate creative minds and develop individuals with the training and passion to innovate new technologies in a safe and productive environment.

F Cubed, LLC, has developed a portable device for the rapid identification of molecules (for example, DNA) outside of laboratories and for use by lay people with minimal training. The product is designed to permit immediate medical diagnosis of potential MRSA[i] (Methicillin-resistant Staphylococcus aureus) infection in abscesses, set the stage for easy and increased surveillance of fruits and vegetables to prevent distribution of contaminated foodstuffs, and allow for the rapid testing of polluted recreational and drinking water. Our technology rests on exclusive licenses obtained from the University of Notre Dame in South Bend, Indiana and the Israel Institute of Technology (Technion) in Haifa, as well as several in-house patented inventions.

The core technology underlying our product is built upon the complex combination of nano-scale electrodes and microfluidic structures that contain a matrix of carbon nanotubes characterized to hybridize with very specific DNA molecules. The hardware that we produce, a disposable biochip, is always the same. The matrix of carbon nanotubes varies by DNA target and is injected by robotic devices into to each biochip assembly in our facility in South Bend. This permits us to offer a wide variety of detectable targets.

F Cubed, LLC works closely with a wide variety of academic institutions and regulatory bodies, including Purdue University, the US Environmental Protection Agency and the US Food and Drug Administration. We have a Cooperative Research and Development Agreement (CRADA) with the US Environmental Protection Agency that is focused on the identification of the pathogenic bacteria Enterococcus in fresh and marine recreational waters. In addition, the US Food and Drug Administration has recently authorized us to begin human clinical trials for our MRSA diagnostic product.

In 2008, the founders of F Cubed, LLC, selected a very difficult technology to develop, at a very challenging time. Like all other new companies we worked diligently to identify and attract investors, all of whom are private individuals with the means to support us, but also with a passion for our mission to create tools to improve health and productivity. We recruited the best employees available, attracting individuals from Pennsylvania, North Carolina, Texas, California, and New York, to our facility in South Bend. All of our employees have classic STEM backgrounds from two-year nanotechnology degrees (technicians managing our production processes) to four-year and advanced degrees needed to conduct our life sciences and research and development efforts.

Benefits Of Federal Funding

Without question, the investors that have underwritten F Cubed, LLC, have been very generous. However, we would not exist today if the underlying science behind our technology had not found support from institutions such as the National Science Foundation and the National Nanotechnology Initiative (NNI)[ii]. F Cubed, LLC, is not a direct recipient of any Federal funding. The inventor of our core technology and Chief Science Advisor, Dr. Hsueh-Chia Chang, is the Bayer Professor of Chemical Engineering at the University of Notre Dame. Dr. Chang and his team have received approximately $3.9 million in Federal grants that were specifically used to develop our technology[iii].

This model will be familiar to the Committee: it works well. Groundbreaking developments in nanotechnology often emerge from academic research and are refined through subsequent attempts to demonstrate applications in specific areas such as medicine or environmental science. In those cases where the related intellectual property is strong, patents are filed, and the technology is transferred to commercial firms, a large percentage of which are start-ups like F Cubed, LLC. These start-ups then begin the process of raising private funds to more thoroughly demonstrate the technology, define the market and potential customers, build prototypes, establish manufacturing capability, and eventually start selling product.

If the process is successful, the start-up grows and becomes financially viable, the university and inventor benefit from royalties that may fund additional research and infrastructure. Recent programs such as the National Nanotechnology Initiative (NNI) have returned US science programs to their creative and application-oriented Edisonian roots. We hope that this model will continue to give US university researchers and US start-up companies a global edge in introducing new technology and solving previously intractable problems.

Federal funds are well placed in an academic environment that can be focused on creative and differentiated research. These institutions have processes in place to encourage and cultivate such research, administer the needed controls to ensure compliance with Federal guidelines, and ensure that funding is properly allocated, expended, and tracked through project completion. Start-up companies, indeed most mid-sized companies, are not always equipped to manage the needed paperwork and processes associated with Federal grants and monitoring programs. Nevertheless, the need for such basic research is great: it fuels start-ups and other companies that look to develop and commercialize technologies.

The current model works well and has resulted in an environment in which companies such as F Cubed, LLC can find exciting technologies to commercialize. We can focus on what we do best: prepare the market place for our products, commercialize the product, and sell solutions to customers in need of them. We can also find like-minded investors who are willing to risk their capital in the hope that they can earn an acceptable financial return.

I would respectfully suggest that funding for basic research in an academic environment is a good social and financial investment. This is especially true for application-oriented research in nanotechnology. Entrepreneurs will find and pursue these opportunities, assuming that the economic environment is supportive, human resources are available, and regulatory obstacles remain manageable.

Importance Of STEM Education

Science, Technology, Engineering, and Mathematics (STEM) education is of critical importance to F Cubed, LLC. In the field of nanotechnology, the availability of well-educated employees is critical. Furthermore, many start-ups choose recent graduates with less experience because they are extremely motivated and enthusiastic as they start a new career and are less expensive in terms of salary and benefits. Nanotechnology as a discipline is new enough that candidates with deep experience simply are not available.

In the field of nanotechnology, STEM graduates come in at least two varieties, and both are of critical importance. The typical STEM graduate would be an individual with a Bachelor of Science, Master of Science, or Doctorate in Chemical Engineering, Mechanical Engineering, Biology, or Physics. These individuals are critical for life sciences work and for research and development activities associated with designing and manufacturing a nanotechnology product.

However, there is another type of STEM graduate that is important and often forgotten in this educational debate. In the area of nanotechnology there are active two-year programs that produce individuals with Associate degrees. The Nanotechnology Applications and Career Knowledge (NACK[iv], a National Science Foundation National ATE Center for Nanotechnology Workforce Development program) Network is a good example of an organization that promotes education in the area and specifically delivers graduates with two-year degrees.

These two-year programs are important because they graduate individuals that have the knowledge and capability to operate and repair the robotic and electronic equipment that is used to manufacture nanotechnology products. Students are trained in environments and with equipment that is specifically used in nanotechnology; indeed, they are able to operate and repair equipment that most four-year and advanced degree STEM graduates would have had little or no exposure to in their educational experience. This is an important distinction: graduates with four-year and advanced STEM degrees expect to work in research and development environments in which they design devices, tooling, and processes. They do not expect to actually work on the factory floor, and are often incapable of doing so or find it to be less stimulating and less challenging. NACK-type two-year graduates are trained to work on the factory floor and, in our experience, have proven to be ideal employees for this work.

The ongoing discussion concerning the need to attract a diverse population of students into STEM disciplines is critical. Companies involved in nanotechnology and other high technology areas will find success and continue to lead the worldwide market place in direct proportion to the availability of such graduates. However, we may endanger our current position and potential for future success if we do not recognize the need for technicians in nanotechnology emerging from two-year NACK-like programs. It is important to ensure that such programs are available, are promoted to potential students, and that graduates are connected to companies in need of these skills.

STEM education is not monolithic. It is critical to support both traditional four-year and advanced degree programs, as well as two-year programs that produce the technicians that actually operate the production lines for nanotechnology products. Successful companies will select the right combination of candidates from each group and find themselves in a much more competitive position. F Cubed, LLC, is a member of NACK and is fortunate enough to have a two-year nanotechnology program offered by Ivy Tech Community College in South Bend. It is the only such program in Indiana, and many states have no comparable programs whatsoever. This deficiency is absolutely worth correcting.

Technology Transfer Challenges And Successes

Technology transfer is a complex process. F Cubed, LLC has exclusive licenses with two prestigious academic institutions and significant experience in identifying technologies and negotiating contracts with technology transfer offices. Such negotiations are like any other large purchase: the buyer wishes to pay the lowest possible price for the most exclusive and flexible license; the seller wishes to receive the highest price possible, limit the scope of the intellectual property offered, and reserve the option to offer similar licenses to other parties in adjacent areas of application.

The hopeful licensee is often a start-up with very limited funding, little or no legal advice, and very little time; the technology transfer office has a wealth of resources, a good deal of time, and abundant legal representation. In addition, intellectual property is the only asset that a start-up has available to use in discussions with potential financial backers; the longer the license discussions continue, the more difficult it becomes to raise funding to begin actual commercialization activities. As a licensee, the most significant barrier to technology transfer is the time consumed in concluding negotiations.

Technology transfer offices try to operate as de facto profit centers for universities, attempting to transform original research into potential cash flow streams for future research or other university projects[v]. Based on our experience, technology transfer offices would prefer to work with established companies, but often find start-ups to be the most interested parties. However, license negotiations proceed in many cases in such a manner that would be expected between two large, equally experienced, and well financed organizations: start-ups are often forced to agree to terms that are less advantageous than desired because they cannot afford to drag out negotiations or continue to fund the ongoing participation of their legal counsel.

It is undeniable that start-ups are the engine that converts such intellectual property into commercially interesting products. Large corporations continue to reduce research and development expenditures[vi] in favor of acquisitions of start-ups that have licensed and commercialized a new technology and, in effect, de-risked the emerging technology. The benefit in the technology transfer process is that when these successful start-ups (which are likely producing a stream of royalty revenue for the licensor) are acquired, the large corporation will use its much greater production and distribution capacity to exponentially increase royalty revenues to the licensor.

Licenses are linked to intellectual property such as patents, and patents are generated with grant funding, often from the Federal government. The difficult dance between offices of technology transfer and start-ups could be made considerably easier by linking the granted funds and concomitant intellectual property with a preference for a reasonably rapid commercialization and licensing processes. That would help remove time as an element of negotiation and lower a significant barrier in the technology transfer process. This would not require a preference for start-ups over established companies; rather it would merely speed up the process and result in benefits for all of the core participants, speed products to potential customers in the market place, provide the tax payers with a quicker return on their investment, and enhance the US economy at large.

It should also be acknowledged that the engine of US economic growth is small business and start-ups are a significant component. Start-ups by definition must hire new employees to commercialize technology. F Cubed, LLC, is still a small company, but we have become one of the fastest growing companies in South Bend. The more technology that is transferred into the hands of small companies, the more new jobs will be created, and the majority of these jobs will be for well-paid STEM graduates who will be able to contribute to their respective communities. Large corporations simply cannot match this process: they typically will roll such technology into existing research and development organizations and rarely enable the type of multiplier effect that start-ups can create.

Success in terms of technology transfer and licensing first requires a definition of success: the most common definition is the ability to raise sufficient funding for the development venture. Investors are attracted to highly differentiated technology, freedom to practice and implement the technology in the broadest possible sense, and creation of a business team with experience and a plan to achieve success in a reasonable amount of time.

F Cubed, LLC, methodically examined more than 100 technologies available from a variety of public and private institutions. We interviewed the inventors and examined the commercialization terms offered by the technology transfer offices. Of course, we examined our own development capabilities and matched technologies with potential investors with passions and interests in certain technology fields. Eventually we selected the University of Notre Dame and started the negotiation process.

The inventor of the technology, Dr. Hsueh-Chia Chang, was anxious to see his work commercialized. We also learned that the US Environmental Protection Agency was very interested in using this type of technology for recreational water testing. Finally, we had connections with potential investors very interested in the area of rapid molecular diagnostics. Through a combination of luck, good negotiating skills, and selling capability, we were able to conclude our first license and raise our first round of funding during the same week.

Our second license with the Israel Institute of Technology was considerably easier to manage because we had funding, an established reputation as an innovator in the area of molecular diagnostics, and influential board members that could help us sway the office of technology transfer. The entire licensing process was concluded in a few months. Time was still important: while we had more money, we also had very expensive legal representation, so concluding the negotiations in a timely manner was vital.

Federal funding is critical for academic research and for technology transfer to companies like F Cubed, LLC. With a few adjustments in the enabling language of the granting process, the Federal government could lower the major obstacle associated with technology transfer: ensure that the institutional beneficiaries of Federal funding are incentivized to quickly commercialize technology and get it into the hands of companies willing to take a development risk that benefits the licensor, the licensee, tax payers who will see a greater and faster return on their tax dollars, and the economy at large.

Nanotechnology Regulation

The materials used in nanotechnology are new and often exotic. These include plastics, ceramics, and metallic nano-scale substrates, as well as a variety of nano-sized particles fabricated from a nearly uncountable number of materials. These particles range from well-known carbon nanotubes, to nano wires, and a variety of particles fabricated from mundane materials such as latex to exotic metal alloys.

Nano materials are used in minute quantities and often are so expensive that companies such as F Cubed, LLC, are economically incentivized to use as little as possible and absolutely minimize waste. As a participant in the life sciences industry, F Cubed, LLC, benefits from an existing array of laboratory and materials safety practices, as well as Good Manufacturing Practices[vii] that are not only customary within the industry, but also required by Federal agencies such as the US Food and Drug Administration and the US Environmental Protection Agency.

For example, raw materials such as carbon nanotubes and related functionalizing chemicals are accompanied by MSDS (Material Safety Data Sheets)[viii] that describe required handling and disposal processes. F Cubed, LLC, like all companies in our space, administer this process through our laboratory safety manager. The state of Indiana, the Occupational Safety and Health Administration, and our lessor / landlord (the University of Notre Dame) periodically review our processes and facilities. While our waste streams are measured in grams and milliliters, they are disposed of through accredited scientific disposal companies.

Each one of our disposable biochips contains micrograms of nano-particles. As the biochip is used, the nano-particles are transported through the biochip and trapped in a hermetically sealed waste reservoir. This permits disposal of the entire biochip through regular hazardous waste channels, ensuring safety and customer convenience.

Our market research indicates that our approach is similar to features found in most life science products containing nano-particles or other nano-materials.

Our experience indicates that research organizations and companies using nano materials handle them with great care. As noted above, these materials are quite expensive, are used in minute quantities, and are often modified through combination with other materials into literally thousands of final forms. While it may theoretically be possible that these materials could be discarded in common solid or water waste streams, this is rare.

Concerns have been expressed that nano materials may have deleterious human health effects. F Cubed, LLC, has no reliable scientific information from our suppliers or academic research colleagues to indicate that there is significant risk. Nevertheless, as a responsible member of our community, we understand that individuals and public entities might have questions about nano materials. For example, concerns have been raised about micro-beads[ix] used in consumer products (toothpaste and other hygiene products) passing through water treatment facilities and entering the environment, where they may disrupt the feeding habits of aquatic animals and result in other unknown impacts.

Micro-bead use is measured in hundreds of thousands of kilograms of homogeneous waste each year. Heterogeneous nano materials are used in quantities that can be measured in tens of kilograms per year and are not discarded in such a way that they can measurably pollute public waters or landfills. That does not mean that nano-materials should be excluded from Federal regulatory efforts, however.

F Cubed, LLC, strongly supports objective and thoroughly peer-reviewed scientific investigations into the potential impact that nano materials may have on health and the environment under the guidance of organizations such as the National Science Foundation or programs such as the Unregulated Contaminant Monitor Rule (UMCR)[x] process established by the US Environmental Protection Agency. Such studies first determine how much nano-material is injected into solid and liquid waste streams. It may be that the quantity at issue is so low that additional regulation is unnecessary, beyond current laboratory safety practices, materials safety practices, and Good Manufacturing Practices. Of course, should such studies indicate the presence of a risk, then the next step would include in vitro testing and epidemiological reviews which are likely to be quite complex given the heterogeneous nature of nano materials.

The US is the worldwide leader in nanotechnology. Our national approach to regulation of nanotechnology must be rational and objective and not driven by misunderstanding of the materials in question or by unsubstantiated fear.

Concluding Thoughts

Nanotechnology is important to our universities, businesses, and consumers, many of whom will benefit from advances in medicine, food safety, and a cleaner environment. Federal funding is a large component of basic research, but the translation of such research into products by privately financed companies must be faster and more deliberate if we our to maintain our worldwide lead. Regulation must be informed and intelligent: safety is paramount and must be focused on the applications at hand. Finally, it is critical that human resources emerge from STEM programs at technician, engineer, and scientist levels because the development and commercialization of nanotechnology products require broad design and production expertise.

Thank you for your support of nanotechnology. I would be pleased to answer your questions.

Summary Of Testimony

- US academic institutions and companies are the unquestioned leaders in the field of nanotechnology, due in large part to an environment that rewards innovation and provides access to the appropriate human and financial resources. We strongly support an investment model in which Federal funding fuels targeted university research and private funding supports entrepreneurs who develop and de-risk technology. Start-ups in this area are an engine of economic growth supplying much-needed products and creating new jobs for recent STEM graduates.

- STEM programs are critical to the development and commercialization of nanotechnology, but they are not monolithic: It is important to encourage continued growth in four-year and advanced degree programs. However, this cannot be done at the expense of two-year programs that have proven to be critical in the education of technicians who are able to operate the equipment and tools that produce nanotechnology devices. NACK (Nanotechnology Applications and Career Knowledge) is a good example of a successful and much needed two-year program.

- Technology transfer is often a battle between highly resourced universities and barely resourced start-up companies. Both parties wish to commercialize technology and solve intractable problems, however the process of licensing is very slow and financially draining. Enabling language in the granting process that incentivizes speed could be highly beneficial in turbo charging this process and permitting start-ups to do what they do best: create new jobs and de-risk technology that can be passed on to larger corporations in the future.

- Creating technologies with new and exotic materials is exciting for those who understand the process and perhaps frightening to others who have witnessed miracle applications turn into health and safety problems. It must be understood that nanotechnology was born into an environment of laboratory and materials safety and Good Manufacturing Practices that were created to limit health and environmental risks. Also, the minute quantity and heterogeneity of nanotechnology materials further reduces their potential risk. Nevertheless, it is incumbent on regulatory bodies and nanotechnology companies to undertake an effort to determine if nanotechnology waste streams are significant in volume (perhaps through something similar to the Unregulated Contaminant Monitor Rule process) and propose regulations that are in line with the associated risk.

Witness Biography

Leslie T. Ivie, F Cubed, LLC

Leslie T. Ivie is President, CEO, and a founding member of F Cubed, LLC ("F3"), an Indiana corporation. He was also founder and Chief Operating Officer of Gas Clip Technologies, Inc. Prior to founding F3, he was Chief Technology Officer at Honeywell International.

Mr. Ivie was instrumental in selling Zurich-based Zellweger Analytics AG to Honeywell international and the later purchase of First Technologies Plc. by Honeywell International. He was also Senior Vice President and Chief Operating Officer of Zellweger Luwa AG in Switzerland after serving as Executive Vice President for Research and Development at Zellweger Uster AG in Switzerland.

He was a founder, board member, and later Chairman of the Board for Textillio AG, an Internet company based in Zurich, Switzerland. Mr. Ivie held a variety of positions at United Technologies Corporation, including Director of the Escalator Business Unit for Otis Elevator Company. In addition to residing abroad in Switzerland, he has lived in Japan, Brazil, and Germany.

Mr. Ivie is a member of the National Advisory Council for the NSF Nanotechnology Applications and Career Knowledge (NACK) Network.

Mr. Ivie graduated from Portland State University with a Bachelor of Science in Mathematics and a Bachelor of Science in Economics and from the University of Denver with a Master of Business Administration. Mr. Ivie holds patents for gas analyzer apparatus and methods of analyzing gases and is an inventor of several pending patents in the area of DNA sample preparation and molecular detection.

End Notes

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i More information about MRSA can be found at: https://en.wikipedia.org/wiki/Mrsa.

ii More information about the National Nanotechnology Initiative can be found at http://nano.gov.

iii Electromagnetically Controlled Self-Assembly of Nano and Micro Colloids for Miniature Medical Diagnostic Kits, Notre Dame-Argonne Frontiers in Material Science Grant, 2003-2005, $200,000 (with I. Aronson).

"Faradaic Micro-fluidic Devices for Complex Fluids", National Science Foundation, 2005-2007, $100,000.

"Risk assessment and management of the Great Lakes species", Great Lakes Protection Fund, 2006-2009, $1,090,000 (with D. Lodge, J. Feder).

"Developing and Applying a Portable Real-Time Genetic Probe for Detecting Aquatic Invasive Species in Ship's Ballast, Great Lake Protection Fund, 2007-2010, $805,000 (with D. M. Lodge and J. Feder).

"Collaborative Research: Development of a Biofluid Transport, Separation and Molecular Analysis System using Microfluidics and a Miniature Mass Spectrometer", National Science Foundation, 2009-2012, $1,500,000 (with P. Bohn, G. Cooke and Z. Ou-yang) joint Purdue-ND project.

"Dielectrophoresis of Nanocolloids: A New Technique for Capturing Biomolecules and Biomarkers", United States-Israel Binational Science Foundation, 2010-2014, $156,975 (with G. Yossifon and T. Miloh)

iv The Nanotechnology Applications and Career Knowledge (NACK) Network is the NSF National ATE Center for Nanotechnology Workforce Development. Through resource sharing, providing course materials, and stressing broad student preparation, we will help create and sustain economically viable nanotechnology education across the U.S. More information about NACK can be found at http://nano4me.org.

v "University Start-Ups: Critical For Improving Technology Transfer", Brookings Institution, November 20, 2013. http://www.brookings.edu/research/papers/2013/11/university-start-ups-technology-transfer-valdivia

vi More information about life science R&D spending can be found here: http://medcitynews.com/2012/12/analysis-healthcare-will-spend-more-on-r-globalization-collaboration-will-rule/.

vii For more information concerning Good Manufacturing Practices, please see: https://en.wikipedia.org/wiki/Good_Manufacturing_Practice.

viii More information about MSDS can be found at: https://en.wikipedia.org/wiki/Material_safety_data_sheet.

ix More information about micro-beads in the environment can be found here: http://www.motherjones.com/environment/2013/09/microbeads-cleanser-ocean-pollution.

x More information concerning UCMR can be found at: http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/index.cfm.