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Raised Bill 551 – An Act Concerning Nanotechnology

Good morning Senator LeBeau, Representative Berger and members of the Commerce Committee. My name is Mitch Horowitz and I am Managing Director for Battelle's Technology Partnership Practice.

I have been asked by the Office for Workforce Competitiveness (OWC) to address questions you may have regarding the emergence of nanotechnology development in Connecticut and the deliberations of the Connecticut Advisory Council on Nanotechnology and the work directed by OWC as it relates to Raised Bill 551, *An Act Concerning Nanotechnology.*

Battelle has served as technical facilitators for the Advisory Council's deliberations, bringing to bear our national expertise and our prior assessment of Connecticut's preparedness in nanotechnology completed in recent years.

Nanotechnology is an emerging area of discovery and innovation that holds great promise in changing the way we live and work, much like what information technology and electronics have accomplished over the last several decades. The importance of nanotechnology derives from the fact that it is both a disruptive technology able to create unique properties and functions for materials and devices and an enabling technology expected to span nearly every market and industry sector involved in goods production.

Already there are more than 200 nanotechnology-based consumer products in the areas of electronics, cosmetics, automotive parts and medical devices. In the future, nanotechnology's impact is expected to change and improve the way we process and store information, generate power, design and deliver drugs, and keep the environment clean.

What makes nanotechnology particularly critical is that it is a driver not only for emerging companies, but for existing companies. Nanotechnology, as one of the key drivers of the next industrial age, will be an enabling technology that will affect not just one industry sector, but will have a broad impacts across many markets and industries in which Connecticut today has a strong economic specialization – including aerospace (30,958 jobs in Connecticut in 2006), industrial machinery (16,280), industrial electronics and instruments (11,710), ships (8,114), pharmaceuticals (9,404) and medical devices

(7,823). These industries, simply put, are the heart of Connecticut's technology-based economy.

To miss the opportunity to grow in nanotechnology as this field emerges would be a strategic mistake. Today, nanotechnology is still emerging. It will most likely offer waves of development over time as new discoveries and innovations take place, similar to how information technology and biotechnology have played out in recent decades. To ensure that Connecticut can be a leader in advancing and integrating nanotechnology into the products of tomorrow means ensuring that Connecticut is among the leading states as the field of nanotechnology emerges over time. Trying to play catch up in nanotechnology in the future is also a recipe for disaster.

Today, Connecticut is at risk of not keeping pace with the development of nanotechnology. While Connecticut has a growing base of activity in nanotechnology across its universities and companies, it is lacking in key infrastructure resources. In particular, Connecticut lacks "go to" comprehensive facilities for state-of-the-art nanoscale characterization (higher structural resolution and detection sensitivity) and prototyping of nano-enabled devices for applications in the physical and life sciences.

Over the past four years, Connecticut has been diligently at work in setting out a path for advancing nanotechnology development in the state. The efforts began with a detailed assessment of the value of emerging nanosciences to Connecticut and the state's competitive position in nanotechnology. Based on those findings, a focused strategy was developed in concert with an Advisory Council drawn from industry, academia, government and economic development organizations in 2006.

The 2006 Nanotechnology Action Plan presented to the Legislature by OWC, in consultation with the Connecticut Nanotechnology Advisory Council, four specific initiatives were set out to advance Connecticut's nanotechnology development:

1. Establish an active nanotechnology product innovation focus by building on the Connecticut Small Business Innovation and Research (SBIR) Office,
2. Pursue a Connecticut Nanotechnology University/Industry Collaboration Initiative,
3. Advance Post-Secondary Education Program Development in nanotechnology,
4. Develop the Connecticut Center for Nanoscale Sciences and Development, a shared use nanotechnology instrumentation facility with related programs.

Through the end of 2007, significant progress has been made in three of these four specific initiatives:

- Nanotechnology innovation grants successfully focused on near-term nanotechnology product development and created partnerships among innovative emerging nanotechnology companies and with Connecticut's large prime contractors who can identify market needs and a path to commercialization. The pilot initiative of the nanotechnology innovation grants focused on fuel cells for unmanned underwater vehicles and three companies received initial awards in 2007 out of eight applications.

- A university-industry nanotechnology fellowship bridge program is currently underway to connect Connecticut industry with leading-edge nanotechnology developments and talent found at Connecticut's research universities. This program supports graduate students and post-docs to address nanotechnology topics developed in consultation between industry and a university. Five pilot projects with UConn and Yale graduate students involving companies across Connecticut are underway.
- A Connecticut Nanotechnology Consortium was formed under the auspices of the Department of Higher Education involving nine Connecticut higher education institutions. The Consortium is now developing a unique statewide Nanotechnology Minor to introduce nanotech to curricula and enable students with basic skills to pursue studies in nanotechnology.

However, in the fourth initiative, Connecticut has not gone beyond assessing and planning for the development of signature "go to" nanotechnology facilities to propel its research base and be a magnet for industry activities in developing nanotechnology applications.

In nanotechnology, the critical starting point for developing, measuring, and testing applications is the use of advanced high-resolution, high-sensitivity instrumentation, whether related to academic research or industrial product development. The promise of nanotechnology was significantly advanced in the 1980s and 1990s with the advent of new tools to see and manipulate individual atoms and molecules; now we are able to translate that scientific research into commercial activities. More importantly, as an enabling technology, it fosters cross-disciplinary research, promoting interaction between the different branches of sciences and engineering to advance the wide spread integration of nanotechnology, irrespective of scale (e.g. macro as well as micro application).

The value of a shared-use nanotechnology instrumentation facility goes well beyond enhancing university competitiveness for federal grants; it also can enable nanotechnology discoveries to be more quickly advanced for proof-of-concept and future testing. A nanotechnology instrumentation facility can also offer an important "hands-on" component for nanotechnology related education and training programs.

A recent field review conducted by a national nanotechnology expert on behalf of OWC and the Connecticut Advisory Council on Nanotechnology found that existing instrumentation facilities in Connecticut lacks the state-of-the-art instrumentation for more comprehensive nanoscale material characterization (higher structural resolution and detection sensitivity). So, while Connecticut's existing nanoscale instrumentation may be adequate to allow standard material characterization, a central "go to" signature facility which would allow nano-scale and nano-enabled device characterization and fabrication,, thereby providing a competitive advantage for researchers, education programs and companies seeking to advance new product innovations does not exist.

The specific gaps in nanoscale instrumentation found in Connecticut, include:

• Advanced tools for "complete" characterization (physical/chemical, organic/inorganic, bulk/surface)

• High-resolution imaging and high-sensitivity analysis capabilities

• Full line of sample preparation equipment

• Structural simulation and molecular modeling tools

• Clean rooms and fabrication for prototyping and enabling the demonstration of nano-scale/enabled devices and systems

• Tools for studying the structure and chemistry of surfaces and interfaces

Given the high cost and technical support required to operate sophisticated nanotechnology tools, experience from around the nation suggests it is best to organize these nanotechnology tools in shared-use laboratories. This allows for a broad access to academic and industry researchers, while promoting specific applications development in focused fields of activity.

State support would enable the Connecticut Center for Nanoscale Sciences to be pursued as a collaboration and co-investment by the State of Connecticut to advance the capacities of existing shared use core nanotechnology facilities found at Yale and UConn as set out in an approach developed by OWC, in consultation with Connecticut Advisory Council on Nanotechnology, in a February 15, 2008 Draft Report entitled, *Connecticut Center For Nanoscale Sciences: Investing in Institutionally-based, Shared Use Nanotechnology Facilities for Research, Education and Product Development.*

With the state as a partner, these two national research universities have agreed to establish a statewide resource, to be known as the *Connecticut Center for Nanoscale Sciences*, to provide the broad academic and industry communities in Connecticut with the tools to advance research, education and product development in nanotechnology, particularly targeted at fuel cell systems and advanced materials, sensors and detectors of chemical, biologic and physical matter and drug discovery and development. In a manner similar to the state's other investments in nanotechnology development, this proposed state co-investment can be undertaken through the state's Innovation Challenge Grant Initiative as provided under Section 4-124hh of the Connecticut General Statutes.

Both UConn and Yale have developed shared-use nanotechnology facilities that can be leveraged to establish more comprehensive "go to" nanotechnology shared-use facilities for both characterization and fabrication tools applied to physical and biological applications at a reasonable cost and with the required highly skilled technical support to make effective use of these tools.

- At Yale, a leading suite of characterization and prototyping tools focused on hard materials will be established with a new state-supported investment in the most powerful high resolution scanning/tunneling electron microscope for imaging and analysis at the atomic level with complementary instrumentation. This new high

resolution imaging tool will be housed at the newly formed Yale Institute for Nanoscience and Quantum Engineering Research and will leverage the availability of Yale's recent investment in a shared-use microfabrication clean room.

- At UConn, advanced characterization and prototyping tools focused on functional and structural materials and on more life sciences applications will be advanced by state-supported investments in atomic scale imaging tools for biological materials along with a prototyping tools. This will be housed and supported by UConn's Institute for Material Sciences, which already has in place a highly successful industry associates program to access shared use equipment and technical expertise involving 30 companies based in Connecticut.

Associated with each of the shared use, core nanotechnology facilities will be faculty research teams offering high level technical expertise to operate the facilities. Teams of expert staff, led by an eminent scientist who will bring additional national stature to the application of these advanced tools, will be needed to operate each of the associated facilities at UConn and Yale. These teams will also provide support staff skilled in sample preparation and instrument operation and maintenance. Service contracts or extended instrumentation warrantees with microscope, detector and other equipment manufacturers will be required to ensure that instruments run safely, without interruption, and to the highest performance standards.

Along with the equipment and technical expertise associated with core nanotechnology facilities, it is critical to have an outreach and single point of contact for the broad base of universities and colleges and industry in Connecticut to access the Connecticut Center for Nanoscale Sciences. This would include a lead program manager and an associate, with resources for marketing materials, in-state travel and database systems. This outreach team will bring hands-on skills in the technical and commercial aspects of solving nanotechnology problems and so serve as a bridge between the user community and the technical experts operating the core lab facilities.

The February 15th OWC Draft Report estimates that the total investment required to launch the Connecticut Centers for Nanoscale Sciences will be nearly $40 million. Approximately $14 to $18 million will go for leading-edge equipment investments, such as:

- Advanced tools for comprehensive characterization and high resolution imaging, such as scanning/transmission electron microscopes, focused ion beam sample preparation, field emission scanning electron microscope, etc.
- Fabrication tools, such as E-beam writers
- Modeling and simulation tools, involving hardware and software

Approximately $21 to $24 million over 5 years will be needed for operating support for staff, including faculty positions, user support and maintenance costs.

A state investment of $20 million is suggested over the next five years to act as a catalyst for creating the Connecticut Center for Nanoscale Sciences in collaboration with UConn

and Yale. This level of funding is viewed as "competitive" in enabling Connecticut to create "go to" shared use nanotech facilities. .

Another $10 to $20 million in direct co-investments by UConn and Yale are expected, primarily towards facilities to house equipment, faculty recruitment and operating support. The remaining sources to meet the funding needs of the Connecticut Center for Nanoscale Sciences will come from federal, foundation and industry support. Federal funding may include both competitive grants for equipment as well as discretionary support. Industry support can include user fees, equipment contributions and other funding support.

In addition to this new direct investment for the Connecticut Center for Nanoscale Sciences, Yale and UConn would bring together more than $20 in "leveraged" university investments for the shared use facility, including Yale's new shared use clean room fabrication facility, the NSF Materials Science Research Center at Yale in collaboration with Southern Connecticut State University, and UConn nanotechnology instrumentation including at the federally funded Nanobionics Device Fabrication Facility and the Center for Cell Analysis and Modeling with capability for live cell and deep tissue imaging of bio-nanostructures and 3D nanofabrication of biological polymers.