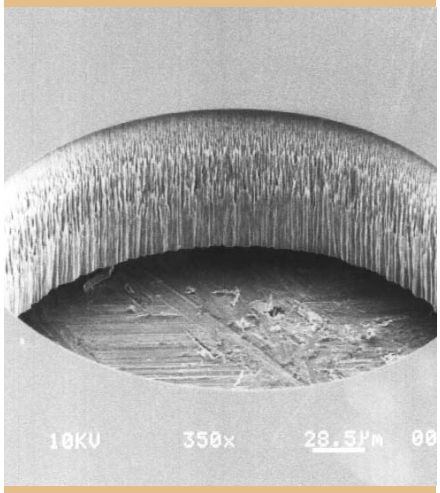
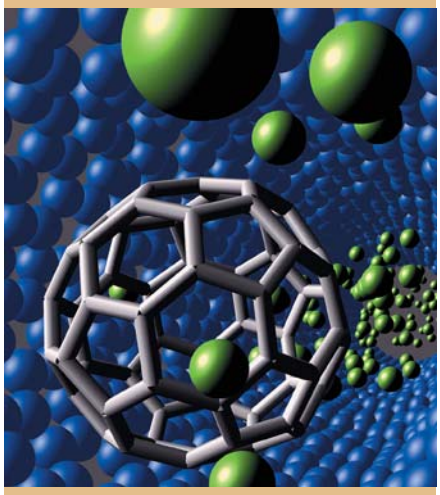
EXECUTIVE SUMMARY





A Call To Action: Advancing Nanotechnology Development in Connecticut

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Executive Summary

INTRODUCTION

Nanotechnology, the understanding and control of matter at dimensions of roughly one to 100 nanometers, is an emerging field of technology viewed by many as leading the next industrial revolution. Indeed, recent progress in the measurement, modeling, and manipulation of matter at the nanoscale has mankind on the verge of revolutionizing materials, data storage and processing, sensors, power generation, environment, and medicine.

For Connecticut, nanotechnology has significant implications for the state's overall economic competitiveness. A recent study for the Connecticut Office for Workforce Competitiveness, *Connecticut's Core Competencies for the Knowledge Economy*, reveals that Connecticut has strategic technology opportunity areas, drawing upon its broad range of core competencies, that can be affected by nanotechnology, involving advanced product development, biomedical engineering, and translational medicine.

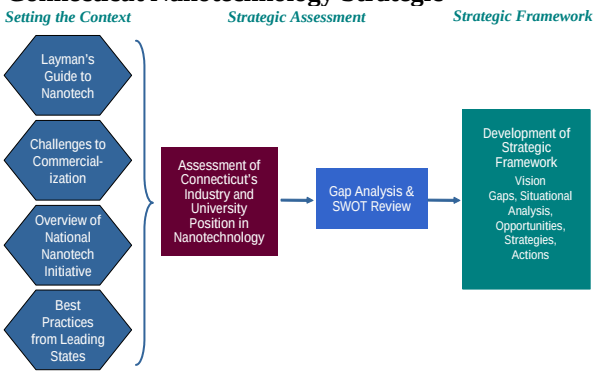
Even more compelling is that nanotechnology can be seen as an opportunity to build upon (a) the natural evolution of Connecticut's long-standing, specialized, and distinctive capabilities to reach ever-diminishing scales of production ("top-down" nanotechnology development); *and* (b) the state's scientific and engineering talent to pursue new materials, coatings, catalysts, and other applications at the atomic scale ("bottom-up" nanotechnology development).

Given the emerging nature of nanotechnology, much of this field is at the stage of fundamental research and testing performed by university researchers and, to a lesser extent, corporate research and development (R&D) laboratories. To develop Connecticut's potential in nanotechnology, it is critical for the state to understand the current position of its universities and industry with regards to research performance and funding, the generation of intellectual property, and the collaboration of industry and university, as well as which specific sectors of Connecticut's technology-rich industrial base are mastering and advancing nanotechnology skill sets and which are failing to do so.

Focus of Strategic Assessment

This report provides a comprehensive examination of the significance to and relative position of Connecticut in nanotechnology. Based on this comprehensive review and analysis, the report lays out a strategic framework for Connecticut to guide future investments and activities in nanotechnology as shown in Figure ES-1.

Figure ES-1. Project Plan for Developing the Connecticut Nanotechnology Strategic



SETTING THE CONTEXT FOR UNDERSTANDING NANOTECHNOLOGY DEVELOPMENT

In setting the context for understanding nanotechnology development, this report points out the following:

- The stakes for Connecticut in nanotechnology are high. Given Connecticut's large and concentrated employment in many sectors that may be strongly impacted by nanotechnology advancements, the estimated employment impacts for Connecticut are expected to reach nearly 31,000 jobs.
- Nanotechnology faces commercialization challenges. These challenges include the oversupply and overlapping nature of nanotechnology intellectual property (IP); the focus of industry investment in nanotechnology on near-term development; the long time frame for commercialization; the uncertain valuation or business model for advancing nanotechnology; the focus of commercialization of university nanotechnology discoveries through new start-up companies; and the approaches such as the prototype phase, bundling nanotechnology IP strategy, and university on-campus user facilities.
- The National Nanotechnology Initiative (NNI) is an asset, but not a program. The NNI is steered by a subcommittee of the technology committee of the National Science and Technology Council, and so may be viewed as an executive-branch "blessing" of certain thematically related R&D activities. It is not a program or "pot" of money to which researchers or states can apply. To attract NNI funding, it is important to understand and reflect the specific requests and requirements of individual government agencies. Perhaps the most important investments made under the banner of the NNI are in nanotechnology-related centers.
- Other states are taking the lead in nanotechnology development. By assessing states that have been successful in winning federal nanotechnology research centers, the Battelle team identified their best practices, including leveraging upfront state and local investments to build competitive nanotechnology programs, matching funds to attract federal R&D centers, using state funds to activate linkages with industry, establishing university consortiums, and integrating nanotechnology education and training.

STRATEGIC FRAMEWORK FOR CONNECTICUT IN NANOTECHNOLOGY DEVELOPMENT

Based on a comprehensive examination of the significance and relative position of Connecticut in nanotechnology, this report lays out a strategic framework for Connecticut to guide future investments and activities in nanotechnology.

Looking to the future, Connecticut will succeed in maintaining its advanced product capabilities by becoming a leading center for the integration of nanotechnology into a broad range of existing and new products, such as novel new materials and coatings, advanced engines, optoelectronic devices, factory systems, testing and measuring equipment, fuel cells, novel detection and sensor systems, advanced drug delivery approaches, and regenerative medical treatments, among many others.

Despite the significance of nanotechnology to Connecticut's future competitiveness in advanced product development, a comprehensive review of the state's position in nanotechnology suggests that Connecticut will be highly impacted by nanotechnology in the future, but is lagging in its current activities. Near-term investments are imperative for Connecticut to participate more actively in the advancement of nanotechnology.

Situational Assessment

Connecticut is clearly playing catch-up in establishing a targeted nanotechnology capacity; the stakes are high if Connecticut is to retain its well-regarded leadership in advanced product development.

- **Nanotechnology can be expected to have a broad reach across the existing industry base of Connecticut.** Industries in which Connecticut has long enjoyed significant economic success and specialization will need to integrate and advance their capabilities in nanotechnology. For instance, nanotechnology-based coatings are making inroads in the harsh environment of turbine engines and in other defense applications, nanotechnology-enabled sensors and filters are being developed for medical instruments and homeland security applications, and new drug delivery mechanisms and therapies are taking advantage of unique nanoscale phenomena. Based on detailed industry-by-industry profiles of the expected impact of nanotechnology on sales revenue, up to 27 percent of Connecticut's goods-producing sector (or just over 30,000 jobs) will be impacted by 2014. ***Failure to make this transition to nanotechnology will place a significant portion of Connecticut's industry base at risk***.
- **Today, Connecticut universities are active in nanotechnology research, but have not reached the critical mass and focus to support a major federally funded nanotechnology research center.** Connecticut colleges and universities receive approximately $12 million a year in R&D support for nanotechnology through the federally-funded National Nanotechnology Initiative (NNI), or roughly 2% of annual NNI funding to universities. While this level of NNI funding is on par with what Connecticut receives of all federal R&D support to universities, Connecticut is in the second tier of states in receiving NNI funding and is notable in not having a designated NNI research center in its borders to further nanotechnology research as in Massachusetts, New York, Pennsylvania and a host of other states. But, the importance of a national nanotechnology research center goes beyond simply the prestige that they offer a state. A federal center of excellence serves as a magnet for promising faculty and students of nanotechnology, often provides a unique shared-use facility that attracts broader industry and university collaborations, and creates a platform for generating additional federal support.

- **Key areas of university research show significant strength and promise in the near term in nanomaterials and the interface of biosciences and nanotechnology and, for the longer term, in areas of nanoelectronics.** In nanomaterials, Connecticut's university research base is engaged in advancing carbon nanotubes, nanoparticles, and nanoelectronics with broad applications for unique coatings, new materials, smaller and more robust electronic and computer devices, improved combustion technologies, inks with novel characteristics, and fuel cells. In bioscience-related nanotechnology, Connecticut's research efforts are engaged in biosensors, tissue engineering, and drug delivery and benefit from the state's strong university and industry biomedical research cluster. Optoelectronics, a particular area of nanoelectronics where Connecticut's research base is focusing, is compatible with the state's long-standing industry strengths in optics.

- **Connecticut is not a "hot spot" of industry nanotechnology activity.** On a positive note, the ongoing study identifies roughly two dozen companies in Connecticut where nanotechnology and nanoscale phenomena currently impact the research, development, products, and near-term business functions and opportunities. Yet, for the most part, the remaining Connecticut companies are not actively engaged in nanotechnology activities. Moreover, many Connecticut companies engaged in nanotechnology are actually conducting this work in their out-of-state research laboratories or with key partners outside of Connecticut. Finally, the vast majority of Connecticut companies needing to integrate nanotechnologies as they advance are acting as spectators rather than participants. The key question is whether Connecticut companies will be able to gain the skill sets and knowledge of advancing nanotechnology and whether that activity will take place in Connecticut.

- **Connecticut is being outflanked by other states because it lacks an investment program.** Other states have actively targeted investments to establish a focus of nanotechnology

Summary of Connecticut's Strengths, Weaknesses, Opportunities, and Threats in Nanotechnology

Strengths

- Growing base of university research with emphasis on several areas of nanotechnology research
- Strong Small Business Innovation Research (SBIR) grant activity of Connecticut companies
- Presence of nearly two dozen companies in Connecticut focused on nanotechnology development

Weaknesses

- No national nanotechnology centers of excellence in Connecticut
- Not a national leader in university or industry nanotechnology-R&D activity as measured by grant and patent activity
- Few large companies engaged in conducting nanotechnology R&D work in-state
- Limited industry-university interactions in nanotechnology R&D
- No significant nanotechnology tools development stemming from Connecticut's machinery/ instruments legacy
- Significant gaps in technology infrastructure

Opportunities

- Strong advanced product development industry complex in Connecticut, needing to integrate nanotechnology in the future to remain competitive
- University and industry strengths in the biosciences in Connecticut, opening opportunities for advancing bioscience-nanotechnology applications
- Proximity to nearby universities and national labs with centers of excellence in nanotechnology research
- Pursuit of commonalities between industry needs and university research in materials, coatings, membranes, filters, and sensors for biomedical, energy, and homeland security applications

Threats

- Lack of state support, making Connecticut less competitive with other states
- Major federal nanotechnology infrastructure investment window coming to a close—difficult to attract a research center to Connecticut with more than 40 centers currently funded
- Federal budget constraints—already expected to impact Department of Defense research funding
- Companies advancing nanotechnology-related product developments out-of-state

research that can enable their universities to build the capacity to attract federal nanotechnology research centers. These states often directly invest matching funds to win these federal research centers. Connecticut is largely absent in its investments in nanotechnology, and even areas of funding that have the potential to advance nanotechnology—such as the Clean Energy Fund—are not being tapped.

Vision and Mission for Connecticut in Nanotechnology

Connecticut by 2015 will be recognized as a leading state in the development and application of nanotechnologies to advance new products by existing and newly formed companies, anchored by a set of well-established nanotechnology research and education assets across its public and private colleges and universities.

To succeed, Connecticut will establish a proactive capacity for industry to collaborate with colleges and universities in identifying and applying nanotechnology-related innovations discovered in-state and from across the world to existing and new markets.

Connecticut will be known as having a world-class infrastructure of specialized facilities to invent, develop, and test new nanotechnology-related applications, along with the research and educational capacities to generate the needed talent pool in nanotechnology skills to develop and attract industry activities.

Proposed Five-Year Action Plan to Move Connecticut Forward

Over the next five years, Connecticut requires a sustained and forward-looking action plan in nanotechnology. The state cannot expect to match the leading states within this period, but can lay the groundwork for raising its competencies in nanotechnology with the following objectives:

- Enhancing the technology infrastructure for nanotechnology research and development to support the development of a critical mass of research and development activity in nanotechnology.
- Creating a national position of recognized excellence for Connecticut in particular areas of nanotechnology, such as nano-materials and nano-biotechnology.
- Creating a culture of collaboration between industry and universities in nanotechnology research and development.
- Capturing more broadly industry activities in nanotechnology product development and its applications, including the location of industry laboratories focusing on nanotechnology development in the state.

Seven Priority Actions

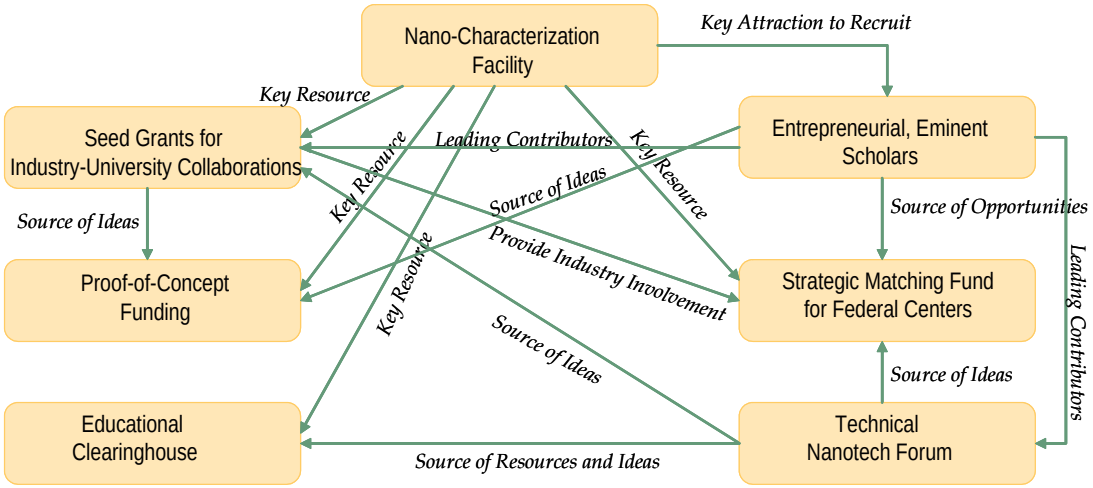
An initial set of seven priority actions is proposed to achieve these goals. These first steps will point to broader and more substantial investment opportunities in the years ahead. But, having these initial investments in place and sustained over a five-year period will be the most critical steps taken by Connecticut.

The seven initial priority actions are as follows:

1. **Establish a state-of-the-art Connecticut Nanotechnology Characterization Facility in a central location to serve Connecticut's public and private colleges and universities and industry from across the state.**
2. **Retain and recruit entrepreneurial Eminent Scholars in nanotechnology across colleges and universities in Connecticut.**
3. **Provide seed grants targeted to nanotechnology for multi-institutional research collaborations and industry R&D partnerships with colleges and universities.**
4. **Develop a Strategic Matching Fund of $15 million to $25 million for future applications for federally funded nanotechnology research centers or major industry nanotechnology laboratories.**
5. **Establish a Technical Nanotechnology Forum that can be a peer-to-peer network for scientists and engineers involved in nanotechnology R&D in the state across the broad base of higher education and industry.**
6. **Create a Nanotechnology Education Clearinghouse to sponsor curriculum development, support professional development of teachers, and encourage access to specialized instructional laboratories.**
7. **Establish a proof-of-concept funding to advance nanotechnology discoveries and validate their potential for commercialization, with active linkage to pursuing federal SBIR funds.**

Individually, each action is an important step to strengthen Connecticut's competitive position in nanotechnology. But together, they can form a highly integrated and reinforcing approach in which each action serves as a resource or a generator of demand for the other actions, as suggested in Figure ES-2.

Figure ES-2. Integrative and Reinforcing Aspects of Proposed Nanotechnology Action Steps for Connecticut



Approaches to Implementing the Proposed Action Steps

If implemented as a dedicated nanotechnology initiative, these seven action steps can serve as the backbone of a more focused "technology accelerator" in nanotechnology for Connecticut. The concept of a technology accelerator was envisioned by the Connecticut Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council as "a focal point to coordinate various R&D, technology transfer and entrepreneurial activities in the state" for defined areas of core competencies.

Alternatively, these seven action steps can be pursued more independently because many can be incorporated into either ongoing initiatives or broader initiatives supporting more than nanotechnology. For instance, nanotechnology can be just one of several technology targets for recruiting entrepreneurial Eminent Scholars to Connecticut or for proof-of-concept funding.

Once the choice of approach is determined, a full-scale prospectus or operating plan can be completed, involving more detailed implementation plans such as specifics on the design, resource requirements, lead organizations, and milestones to be achieved.