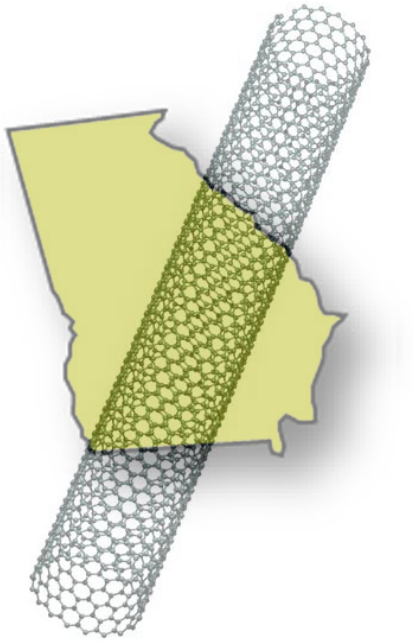
Characterization of State-Level Nanotechnology Policy Initiatives and What It Means for Georgia



By: Patrick E. T. McKeon

Conducted through support of the Georgia Innovation Internship, the Enterprise Innovation Institute, and the Center for Nanotechnology in Society at Arizona State University (CNS@ASU)

As part of the Science, Technology, and Innovation Policy (STIP) Program,
a collaboration between the Enterprise Innovation Institute and the School of Public Policy at the Georgia Institute of Technology
Atlanta, Georgia

Summer 2008

Table of Contents

0.0 Executive Summary

The story of nanotechnology has come far from its theoretical conversation in 1959. Since being able to visualize at the nanoscale we have developed technologies that reach the heart of our imagination, and yet are actually part of over 600 products available to us as consumers today. There has been a series of initiatives at the federal level, including the National Nanotechnology Initiative, to promote the activities surrounding the research and development of nanotechnologies, as well as the teaching of those concepts to student and the general public. In addition to these initiatives from the national level, there have been some states that have established initiatives on their own to bolster and complement the efforts from the national initiative. The employment of technology-based economic development was seen as proper to leverage nanotechnology to generate new knowledge, products, jobs, industry, and resources.

Among the states competing to establish themselves as a leader in nanotechnology, Georgia is positioned highly in terms of research and has modest development already. With the progress in the state in developing their infrastructure the next step is to assess the capacity for a strategic initiative to assist the efforts in the state. To find appropriate suggestions for methods to achieve advancements in nanotechnology this study looked at a selected group of states from across the country to identify their initiatives and the ways in which they worked. Following the investigation into the initiatives they were systematically categorized based on the major partners in the initiative and the structure it utilized to push forward on its goals.

Depending on the level of sophistication, the base industries, and the infrastructure components in the state there was a distinction into models that were identified as a consortium, industry, university, or agency model. The focus of a consortium model is to increases awareness and advocate for nanotechnology activities. The focus of an industry model is to use private partners to increase research and commercialization. The focus of a university model is to use public partners to increases research, commercialization, and educational programs. The focus of an agency model is to monitor and adjust the policy mix of the initiative to respond to the fluctuations of the situation.

Various states of differing backgrounds established extensive infrastructure, many collaborations, strategic research funds, industrial partners, and prominent researchers to increase to effectiveness of their up-stream research activities. Some states created centers with their industrial partners, utilized university center technology transfer offices, promoted start-up ventures, and allowed for regional innovation clusters to increase the rate of down-stream research commercialization. Other states made sure to assemble workforce development programs, nano-specific degree programs, and public outreach and informational campaigns to help train the next wave of nanotechnologists and the public they will serve. Lastly, some states leveraged the existing high-technology based industries within their borders to prepare for the next wave of technologies.

For the state of Georgia to move forward with the development of nanotechnologies they should put together a plan to act in the near term. In the next five years there should be an series of directives to create a nano-related consortium, to strengthen the efforts of the university centers' technology transfer offices for nanotechnology, to continue to recruit eminent scholars in nanotechnology to the university system, to develop additional infrastructure around the state and increase the collaboration among its various researchers, and lastly to create a pair of funding accounts for nanotechnology research projects as well as for nanotechnology start-up ventures. Furthermore, the state should look to develop a strategic initiative with goals for the long term. In the future of a developed area there should be a more developed model to operate from, the creation of workforce development and nano-specific degree programs, the establishment of centers to address traditional industries and the recruitment of additional similar industries from the area, and the continued improvement in the achievement record for the primary and secondary education institutions in science, technology, engineering, and mathematics subjects.

1.0 Introduction

The purpose of this section is to introduce the topic and the key concepts to be discussed in this work. This will involve discussing the academic topic of technology-based economic development, the technical term nanotechnology, the history of nanotechnology, the current policy initiatives shaping state-level actions, and the current interest in nanotechnology.

1.1 Technology-Based Economic Development

The point of having this discussion in the context of policy has to do with the overlapping of scientific research with regional development in technology-based economic development. Technology-based economic development is referring to the concept that the creation of an innovation allows for economic growth through improvements in existing products, the creation of new products, the creation of new jobs and industries, and the increased standard of living for the public. Additionally, the place that is the source of the technological innovation stands to benefit the most from the development of industry and the location of resources surrounding the cultivation of the innovation. It is with this in mind that the frame for this study comes from. Technology-based economic development has been employed in states since the 1980s to advance manufacturing or increase applied research.[1] By studying the ways in which areas try to develop nanotechnologies, there are lessons to be learned in how to follow-suit and develop the innovation as well to share in the benefits and the growth. To have sufficient growth there is a rough progression, and usually there is also a feedback chain, from which there is the establishment of infrastructure for the production of the research, the support to carry-out the research, the talent to perform the research, the results of research, the training of new talent, the development of commercial products, the adoption of the product in the market, the capital funding for growth, the incorporation of industry, and overall economic gains.

[1] http://www.ed.psu.edu/cshe/nano/Papers/Nanotechnology_and_the_States.pdf

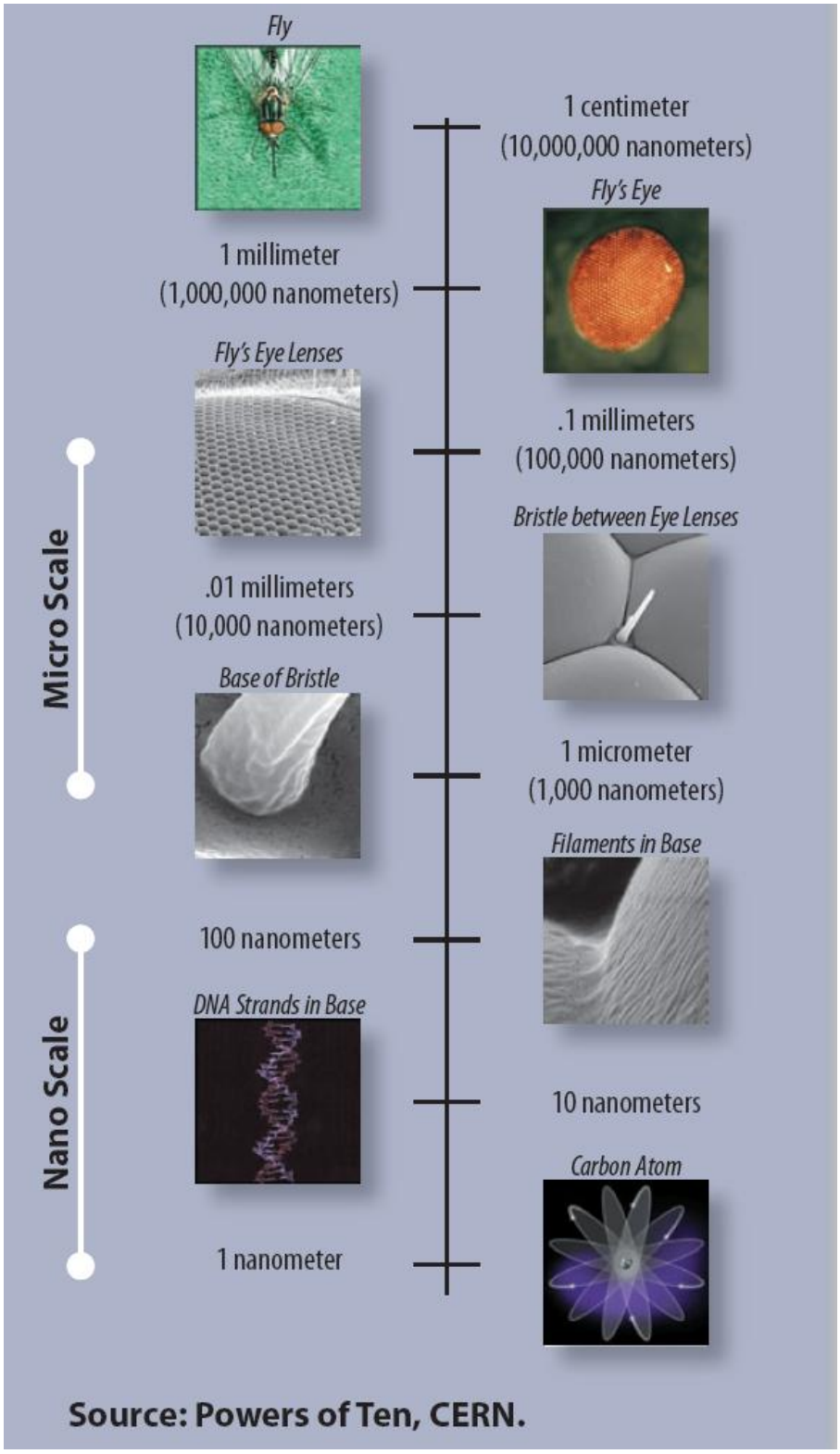


Figure 1.2.1. A diagram to illustrate the level of scale for the discussion of nanotechnologies. The hash marks on the scale indicate the change in one order of magnitude, meaning one power of ten.

1.2 What is Nanotechnology

When considering nanotechnology it is customary to establish a definition for the term so that the context of its use is understood clearly. According to the National Nanotechnology Initiative, nanotechnology has three important characteristics as necessary criteria:

1. There is an intentional manipulation of matter
2. The matter being manipulated in on the length-scale of 1-100 nanometers
3. The properties exhibited by the material are unique to the length-scale as compared to their properties as bulk material

What this means practically is that there is a designed use of the materials, which satisfies it as a "technology." Also, that we are at the range below micro and above atomic, to satisfy the "nano." Lastly, there is a consideration that the qualities and interactions observed from this scale are distinct from what properties we see at the micro-scale and larger.

1.3 The History of Nanotechnology

After the idea of nanoscale technologies was discussed by Richard Feynman in 1959 there had to be the ability to visualize at the nanoscale level to be able to perform even the most basic of sciences since observation is an indispensable component to scientific inquiry. With the development of the Scanning Tunneling Microscope in 1981 and the Atomic Force Microscope in 1986, the ability to witness near the atomic level became a reality.[2] Many investments and advancements through the end of the 1990s set the stage for a series of federal initiatives to harness the potential at the nanoscale.

1.4 The National Nanotechnology Initiative

In July 2000, then President William J. Clinton presented the National Nanotechnology Initiative to accomplish a series of goals for the generation of knowledge and the development of technologies from nanoscale research activities

[2] http://www.foresight.org/nano/history.html

with a large pool of funding. The National Nanotechnology Manufacturers Network was included in the initiative, and had been created in April 1994 to help put nascent nanotechnologies into production at one of the five regionally diffuse centers where user-access was allowed to these costly instruments.[3] Nonetheless, in March 2004 this was revamped to the National Nanotechnology Infrastructure Network as a series of one dozen research facilities with cutting-edge facilities for nanotechnology research and development.[4]

Having federal resources and drive to foster growth in nanotechnology development there was a push to use the available resources across the country if possible. What happened next is that states assembled initiatives to increase and complement the national initiative so as to utilize the resources provided to a higher level of benefit. What shall become evident through the course of the paper is that different states took to different aspects of the initiative, and worked to modify their efforts to accommodate the status of their own state.

1.5 The Status of Nano

With nanotechnologies being real, and not science fiction, there is a growing base of research and an expanding list of over 600 consumer products that are nano-enabled.[5] The push forward is being made not only on the side of research and development but also on the side of philosophy and ethics. Since the public hesitance over the emergence of biotechnologies it has been seen as appropriate to include within emerging technologies a sense of what the public is interested in having science study and industry develop. This has been seen as a way forward to prevent the horrifying scenarios proffered in the news and entertainment media. The efforts of society to block nanotechnology have not been easily evident. It would seem that nanotechnology is safe at present, but it could soon be seen that the advancement of its development could be accompanied by confusion or outcry. Nevertheless, the opportunity to develop what some consider the next industrial revolution, and still others consider the next great general purpose technology that

[3] http://www.wtec.org/loyola/nano/US.Review/03_05.htm
[4] http://www.nnin.org/nnin_faq.taf?_type=general
[5] http://www.nanotechproject.org/inventories/consumer/analysis_draft/

will spread across many platforms and products, is too great to be put on the shelf. Should it be the case that nanotechnology provides a nearly universal innovation in the way in which society operates and exists, the potential for growth and benefits is far beyond what is reasonable to express.

2.0 Nanotechnology and Georgia

The purpose of this section is to outline the history and progress of nanoscale research and technology development in Georgia. This section is to meant to frame the discussion in Section 6 as to what are appropriate recommendations to make for the future policy formation in the state of Georgia. It is also to show the level of interest and involvement in the state so that the rationale behind making any subsequent decisions is justified for this region. This is a picture of the activities in Georgia in terms of research activities, commercial activities, and policy initiative already in place.

2.1 Nanotechnology Research in Georgia

Georgia has been advancing in research in emerging technologies over the last two decades. When looking at the earlier up-stream research activities in nanoscale technologies it becomes apparent that the majority of the activity around the state does aggregate in the greater Atlanta region. [6] There are three centers federally sponsored research centers including the Microelectronics Research Center (through the National Nanotechnology Infrastructure Network), and both the Center for Personalized and Predictive Oncology and the Detection and Analysis of Plaque Formation hosted jointly with Georgia Tech and Emory University as Centers for Excellence in Cancer Nanotechnology funded through the National Institutes of Health as part of the National Nanotechnology Initiative. In addition to this, there are four research groups at Georgia Tech and two research groups at the University of Georgia whose focus is on nanoscale science and engineering principles.

2.2 Nanotechnology Industry in Georgia

In Georgia there is a noticeable and developing presence in the development of nanotechnologies. The state has been the site of over 700 nano-related patent issuances to almost 70 different assignees. There are many developments that are being processed and commercialized in Georgia, from Kimberly-Clark Worldwide, to the Georgia Tech Research Corporation, to the Coca-Cola Company, to Dow Chemical, to the Intel Corporation, to Lucent Technologies all have had patent

[6] Jan Youtie and Philip Shapira. "Mapping the nanotechnology enterprise: a multi-indicator analysis of emerging nanodistricts in the US South." Journal of Technology Transfer (2008) 33:209-223.

activity in nano-related filings according to analysis from the Enterprise Innovation Institute. There is not an overabundance of private research and development in the state in general terms,[7] but there is certainly some activity from well established operations to develop novel uses of nanoscale improvements to incorporate into existing products. A recent press release touts the merits of the 2008 Innovation Award winning nano-enabled hull and deck material, NanoXcel, developed to improve the performance of personal watercraft by Yamaha Motor Corporation headquartered in Kennesaw, Georgia.[8]

By working with the developed corporations proves useful in commercializing nanotechnologies, but do not count-out the start-up ventures. In Georgia there are already twelve start-ups identified in the patent analysis from the Enterprise Innovation Institute. These new ventures often do reach issues with finding sufficient funding to fully develop their technologies, but having them allows for innovations and at the very least provides a resource for new ideas to the developed industrial players. Leveraging the new nanotechnologies to established firms can help them when their internal research and development is diminished.

2.3 Nanoscale Initiatives in Georgia

Georgia has been working to develop its nanoscale infrastructure with intent on establishing some prominence in the field. Although the main policy entrepreneur in the research arena in the state is the Georgia Research Alliance, it has demonstrated its ability to push for advancement beyond simply its dedicated mission of developing biotechnology with its assistance in lobbying the state government to purchase equipment and create a new Nanotechnology Research Center. The developments the state has seen in the recent past include:

- 2003: Georgia Tech is named a member of the National Nanotechnology Infrastructure Network

[7] Jan Youtie and Philip Shapira. "Mapping…" pg 220.
[8] http://www.nanovip.com/node/5468

- 2004: Emory University and Georgia Tech are awarded three Centers for Excellence in Nanotechnology
- 2006: Swainsboro opens the National Nanotechnology Manufacturing Center
- 2006: The State of Georgia allocates $45 million for a new Nanotechnology Research Center at Georgia Tech

The state is positioning itself to be a key stakeholder in the emerging nanotechnologies sector. Georgia has five universities boasting one dozen research groups focused on advanced technologies, seven of them concentrated solely on nanoscale research. Seeing as this is believed to be a cross-cutting (general purpose) technology, the amount of potential benefit from expansion in this area is great. That is also a decent explanation for the intense competition to be situated as the dominant regional center in nanotechnology, hence the state-wide initiatives.

3.0 Research Design

What follows in this section is a description of the process by which the actions of this study were devised and carried out to provide the results and recommendations provided in the later sections of this report. The basic structure involves performing a literature review, determining the aspects of policy to consider, identifying the states for investigation, and establishing a systematic process by which to classify and characterize the findings.

3.1 Literature Review

A literature review was conducted to gain an understanding of the status of the field of nanotechnology policy. Through this review it was discovered that nanotechnology policy is a convergence of research policy, economic development policy, and philosophy of science at the nanoscale. There is work that discusses the ways to promote effective research in public facilities. There is work that discusses the ways to effectively transfer technology from the laboratory to the commercial market. There is also work that discusses the ways in which the public ought to be engaged into the priorities of developing these nascent technological advancements poised to profoundly impact society. Many of these points were provided in the introductory section of this work and should need little additional consideration here.

3.2 Goals of the National Nanotechnology Initiative

After determining the potential scope of the topic, the next important step was to set the parameters for the investigation based on a policy framework. Seeing as one important reason for developing state-wide policy initiatives is the existence of the national initiative,[9] there was a need to understand the role of the National Nanotechnology Initiative and what it was promoting for this emerging technology. By going through the progression of the National Nanotechnology Initiative from its first presentation in July 2000 by President William J. Clinton through its latest assessment in April 2008 under President George W. Bush there is a clear sense of what is planned for, expected, and anticipated from the developments in this cutting-edge research. Although the specified goals have shifted slightly through the change

[9] http://www.nano.gov/041805initiatives.pdf

in administrations the goals to be highlighted in this project are based upon consistent objectives found in the versions of the initiative as they pertain to further policy designs. The following are the four important goals to keep in mind as the characterization unfolds:

1. To promote and develop up-stream research activities in nanoscale science and engineering
2. To promote and develop down-stream research and commercialization activities in nanoscale science and engineering
3. To promote and develop the translation of skills in nanoscale science and engineering to the next generation of researchers and the modern workforce
4. To promote the increase in economic activities in the area of development as well increase the benefits to society from the responsible development of nanotechnologies

Using these national goals will help in assessing the establishment of sub-national (specifically state-wide) policies to enhance and complement nanotechnology development in this study. It is appropriate to mention here that part of the fourth goal of the National Nanotechnology Initiative (responsible development) also includes the consultation of the public and the incorporation of societal interests for nanotechnology, which have been placed within the third goal of educational objectives for the purposes of educating the public, teaching students, and training workers being seen as a means of actively engaging public support in nanotechnologies through their own participation. Public sentiments will also be evident from the support of the products generated from the development of nanotechnologies.

3.3 States to Investigate for Policy Initiatives

To identify the states most appropriate for this study it was important to determine which states are receiving acclaim for their efforts in nanotechnology from respected sources. In consultation with advisors involved with the internship there was an explicit desire to cover states of various backgrounds, to expand upon previous work

in-house studying the southern region, and to cover states of various sizes. Upon further investigation of reports generated by the National Nanotechnology Initiative, Lux Research Incoporated, Small Times Publications, and the National Governor's Association a series of states were selected to cover various sizes, industrial bases, regions, and levels of development.

The National Nanotechnology Initiative, through the Subcommittee on Nanoscale Science, Engineering, and Technology of the Committee on Technology of the National Science and Technology Council from the Executive Office of the President, has published a few Strategic Plans, Assessments, and Workshop Reports which have highlighted certain practices at the state-level. Lux Research periodically published the highly reputed Nanotechnology Report, of which the fourth (2004) and fifth (2007) versions were reviewed for states assessed. Small Times Publications produces the industry standard *Small Times Magazine* which includes ranking of states for potential in nanotechnology development, as well as assessments of universities for micro- and nano-scale research activities. Most recently the rankings published in the May/June 2007 issue included peer rankings of universities to be included with their internal analysis. The National Governor's Association published a series of reports from its Center for Best Practices as part of chair Governor Janet Napolitano's Innovation America initiative in 2007.

Figure 3.3.1 shows the states investigated with shading. Geographically there are states from the northeast (Massachusetts, New Jersey, New York, and Pennsylvania), the southeast (Georgia, North Carolina, Tennessee, and Virginia), the midwest (Illinois, Michigan, Minnesota, and Wisconsin), the southwest (Arizona, Colorado, New Mexico, and Texas), and the west (California, Oregon, and Washington).

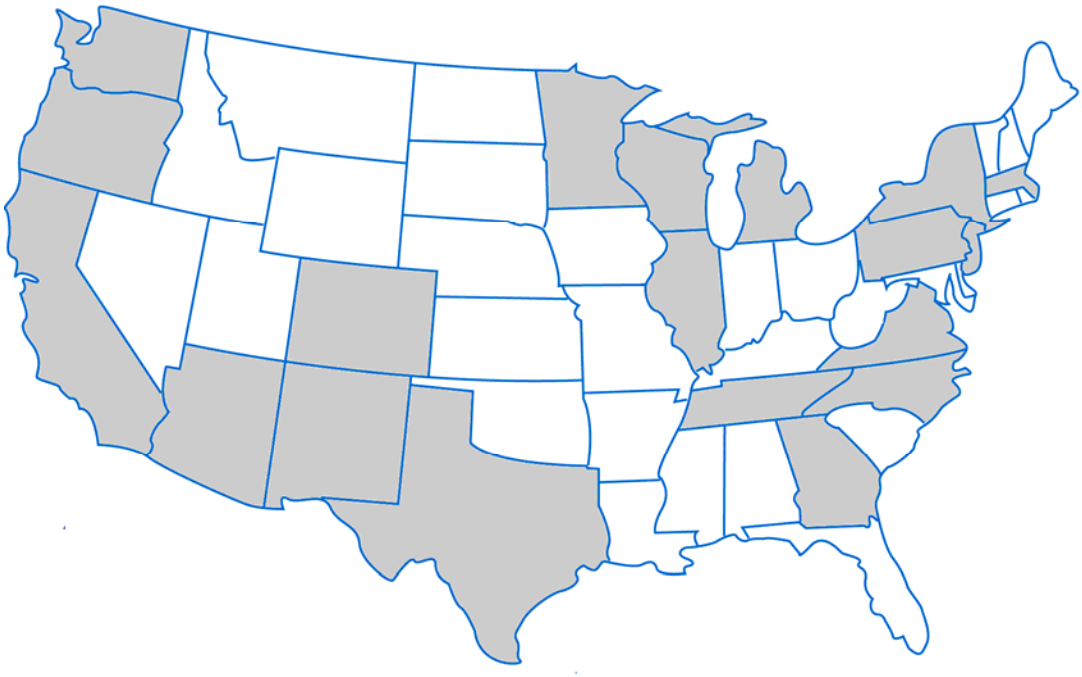


Figure 3.3.1. Map of the continental United States with shading of the states that are discussed as a part of this study. Those states are: Arizona, California, Colorado, Georgia, Illinois, Massachusetts, Michigan, Minnesota, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Tennessee, Texas, Virginia, Washington, and Wisconsin.

3.4 Models of Characterization for Policy Initiatives

When looking to characterize the states investigated into a systematic framework there was a demonstrated need to use a developed organizational structure. The following series of model divisions were adapted from the work presented in the Report on the National Nanotechnology Initiative Workshop on Regional, State, and Local Initiative in Nanotechnology.

3.4.1 Consortium Model

The focus of the consortium model is to increase awareness of nanoscale activities and to provide advocacy for their advancement. It is usually a nascent organization looking to build a critical mass of key players and resources to expand the sector. The consortium model consists of a group of interested parties that work to facilitate the exchange of information between other stake-holders and those actively involved in nanoscale science

and technology research or development. It is rather common for this informational exchange to take place through a consortium e-mail list, website, newsletter publication, or conferences and conventions. They also generally engage in active lobbying to local and national levels of government to help secure the development of research infrastructure, an increase in research grants, and an increase in assistance to small business support or technology transfer programs. These efforts are helpful in establishing contacts to increase awareness locally about the advances and activities being conducted.

3.4.2 Industry Model

The focus of the industry model is to advance research and commercialization activities. The industry model consists of a group of private companies (sometimes a group of one) that build a relationship with a university research center, and pledge matching funds to complement state (and potentially federal) investments in new facilities and equipment for the exclusive use of a particular section of the facilities, or the opportunity to influence the direction of the entire enterprise at this location. Typically there is also an expansion or relocation of the industrial partners to build private research facilities near-by for collaboration and access to the other researcher at the center. This helps grow the industrial partners involved, as well as the area surrounding the centers, and provides a usually large amount of resources for the university and state to leverage.

3.4.3 University Model

The focus of the university model is to advance research activities and to educate future researchers and practitioners of nanoscale science and engineering, with additional effort to commercialize any novel creations. The university model consists of a group of university research centers established for, or joined together for, the purpose of building and expanding upon facilities to develop further nanotechnology research activities. This state funding is sometimes accompanied by matching federal support, and is

provided under the provision that parts of the research center must be available for use by those unaffiliated with the university whether they be private researchers or those from other schools. It is sometimes also included within the university a nano-specific degree program as well as space in the research center for a series of laboratories designed to be used for those seeking nano-degrees. This establishes a prominence to the universities with centers and creates a high concentration of skilled laborers for industry to acquire.

3.4.4 Agency Model

The focus of the agency model is to select, monitor, and adjust the policy mix for the advancement of nanotechnology under its own authority. The agency model consists of a separate government entity that is charged with acting in the best interest to promote nanoscale progress across any or all of the potential goals of the initiative. The agency is usually a public corporation which directs its state allocated funds to build facilities, support research, leverage private investment, assist business ventures, or attract researchers. Being funded through the government on a consistent basis it removes the need to lobby the state, and it is given the avenues to report directly to the government.

4.0 Results

The following information is presented based upon the findings from this study. This section will detail the information ascertained from the inspection of state-level policy initiatives for nanotechnology research and development. The states are grouped into sections based on its placement within the developed methodological models from the evidence produced. This is meant to be an objective look at the policies in place, is intended to highlight the practices of the state, and required actions from a unit of the state government to be included as a policy provision.

4.1 Consortium Models

Based on the investigation into the states mentioned, four of them are being classified as having a consortium model: Arizona, Michigan, Texas, and Virginia. These efforts are being classified as such for their being mostly informational in nature, and that their connections to larger efforts state-wide are not explicitly and selectively for nanotechnologies. Recall that the consortium model has a focus of providing greater awareness as well as advocacy for further development.

4.1.1 Arizona Nanotechnology Cluster

The Arizona Nanotechnology Cluster was formed in January 2003 as a non-profit organization with the mission to share technological advances, to promote business development, and to build a large organization with connections through its membership to various levels of industry, government, and academia in Arizona. This consortium is a public-private venture by the connection of its membership to researchers in the state's university system. Though there are no direct state appropriations to the consortium there is a connection through active membership to the Advanced Microsystems Laboratory and the Microelectronics Design and Test Laboratory at the University of Arizona, as well as the Nanostructures Research Group and three research groups within the Biodesign Insitute at Arizona State University. Arizona State University opened its 175,000 square-foot Biodesign Institute in December 2004 and expanded another 172,000 square-feet by January 2006 after $69 million dollars of university

funding followed by $78.5 million of State Research Infrastructure funds. It has among its components the Center for BioOptical Nanotechnology.

The main thrust of the activities of the group include hosting the website, http://www.aznano.org/, publishing an e-mail newsletter, hosting a monthly meeting, organizing an annual Nanotechnology Symposium, and lobbying the national and state governments for the location of federal laboratories and additional nanotechnology infrastructure in Arizona. Their mission also charges them with educating the public about nanotechnology and related issues, but other than the information provided to all members there does not seem to be a concerted educational component. It is interesting to note that membership is free of charge and open to all.

Other state actions that are helpful to nanotechnology include the 2001 passed Proposition 301 and the $112 million it had raised in five years. The proposition created a 0.6% sales tax increase for education which is directed to the Arizona universities have increased the support of their technology transfer offices, and have added money to the state's Technology and Research Initiative Fund, which is used to fund research and technology development across the state.[10] Furthermore, Governor Janet Napolitano has established the Council on Innovation and Technology in 2003 to serve as the group to help analyze and produce new economic development strategies that improve the Arizona knowledge-based sectors.[11] The council also has goals to stimulate technology transfer from the university system and to create policies that attract and leverage private sector capital investments. The council has put together efforts on biotechnology that helped encourage the Biodesgin Insititute but have not yet addressed nanotechnology specifically.

4.1.2 Michigan Small Tech Association

[10] http://www.matr.net/print-19967.html
[11] http://www.gcit.az.gov/

The Michigan Small Tech Association was formed in 2003 as a non-profit organization foster growth in the emerging small tech sector of advanced micro- and nano-technologies by releasing information pertaining to the research achievements and the business issues in the sector in Michigan. This consortium is a public-private partnership which is connected on the public side by the Michigan Economic Development Corporation and the university system, which is partnering on the private side with the reputable Small Times Media group. The reason it would not be better suited as an agency model system is due to the fact that Michigan Economic Development Corporation shows no transfers and would at most be providing a small amount of money for operations of the informational campaigns.

The main activities of the consortium are the hosting of the website, http://www.michigansmalltech.com/, and publishing the newsletter "Michigan Small Tech Journal." This consortium is currently in suspension of activities, for reasons that could not be confirmed with the organization. The resources that were available on the website included a directory of small tech businesses, and a linking of university technology transfer offices so that those involved in the small tech research or development activities could more easily connect for collaborations or assistance. There was also an interest in providing the informational services to policy decision-makers, which is why they were allowed to join the association.

Michigan has a wealth of other activities to benefit other industries and business as a whole. The Michigan Economic Development Corporation uses the state resources in the Michigan Strategic Fund to coordinate the activities of the various boards and initiatives. Some of the boards include the Strategic Economic Investment and Commercialization Board and the Michigan Economic Growth Authority Board. There are also targeted initiatives in alternative energy, life sciences, homeland security and defense,

and advanced manufacturing.[12] The general initiatives include the Capital Market Development Initiative, the Venture Capital Funding Initiative, the 21st Century Investment Fund, the 21st Century Jobs Fund, the Angel Investment Network, Michigan Small Business and Technology Development Center, ConnecTech, Accelerating Michigan Entrepreneurs, Michigan SmartZones, and the Michigan Universities Commercialization Initiative, to name some. Any of these outside activities could be used to further the nanotechnology sector, however none of these policy devices were designed nor designated to influence nanotechnologies.

4.1.3 Texas Nanotechnology Initiative

The Texas Nanotechnology Initiative was formed in 2002 as a private non-profit organization with the goals of bringing companies, researchers, and resources together to promote rapid growth and commercialization for nanotechnologies in Texas. This consortium was expanded to include a few members from the University of Texas at Austin and Texas A&M University and could be characterized as a public-private group. There are no directed transfers of state funds to this consortium.

The main activities of the group include hosting the website, http://www.texasnano.org/, and using it as a means to help connect university researchers, industry leaders, private investors, and government officials to each other and the resources to enhance nanotechnologies in the state. There are some activities that are part of the initiative that include lobbying the state for some directed assistance and infrastructure development. It permits the inclusion of other states to join its initiative knowing that Texas will remain the primary focus, but that any national issues or lobbying can be helpful to other member states.

Texas has put less effort into the state-wide effort due to the actions and success of local initiatives for business growth and technology development

[12] http://www.michiganadvantage.org/targeted-initiatives/default/aspx

in places such as Austin, Houston, and San Antonio. There are policy actions which are broader, such as the $200 million Texas Enterprise Fund and the $300 million Texas Emerging Technology Fund, which are used to promote and develop new business ventures including in advanced technologies.[13] The state has also allocated $40 million to the Advanced Materials Research Center in collaboration with SEMATECH. There is also a regional network of Centers for Innovation and Commercialization that are used to aid the state's Industry Cluster Initiative. The state has established some of these programs in response to the plans for the Texas Technology Initiative and the State Strategy on Advanced Technology, which included among its desired benefactors to be nanotechnology as well as biotechnology, microelectronic-mechanical systems, advanced energy, semiconductors, and wireless technologies. These plans also included the development of a roadmap for development and a series of other policy initiatives such as leveraging private investment, creating Centers of Excellence in the university system, and bolstering interest and quality in the K-12 science education programs.[14] [15]

4.1.4 Virginia Nanotechnology Initiative

The Virginia Nanotechnology Initiative was started in 2002 as a non-profit organization, under the name of INanoVA, with the purpose to promote collaborative research, workforce development, technology transfer, and commercialization activities among the state agencies, university centers, federal laboratories, and industrial partners within Virginia. This consortium is a public-private endeavor and is supported by annual funding of no more than $250,000 from the state government corporation, the Center for Innovation Technology. This is not classified as an agency model because the interaction is purely a financial allocation to support its activities. There are many partners from the university centers, federal laboratories, and private industry represented in this group.

[13] http://www.governor.state.tx.us/divisions/bpp/budget/files/budget08-09.pdf
[14] http://www.txti.org/docs/tti.pdf
[15] http://www.txti.org/docs/ssat.pdf

The main focus of the organization includes hosting the website, http://www.vanano.org/, and lobbying for greater support of research programs, commercialization capital funding, workforce development programs, and nano-specific degree programs. It has linked universities together so that there could be shared graduate level nano-courses through the Commonwealth Graduate Engineering Program and prompted the state's Joint Commission on Technology and Science to plan for a more developed state-wide strategy. The Joint Commission on Technology and Science had put together a whitepaper jointly through its Nanotechnology Research and Development Committee and Manufacturing Advisory Committee in 2006, and then created the Nanotechnology Authority Advisory Committee in 2007 to study and make recommendations based on the whitepaper.[16]

The state has other initiatives that are more directed towards biotechnology, as well as general programs like the Commonwealth Technology Research Fund, the Higher Education Research Initiative, the Innovative Technology Authority, and the Virginia Economic Development Partnerships to bolster efforts to generate research, to commercialize, and to promote advanced technology development throughout the state.[17] [18] Should they develop through the Innovative Technology Authority a nanotechnology plan in a similar model to their biotechnology efforts, there would be great promise for them to find results in nanotechnologies as well.

4.2 Industry Models

After investigation three of the states inspected are being classified as having the components to an industry model: California, New Jersey, and New York. The classification is based upon the extensive and active role of the private partners to invest in the infrastructure and participate in the operations of the research activities.

[16] http://jcots.state.va.us/siglegrep.htm
[17] http://www.cit.org/programs/r_and_d/ctrfrelease.pdf
[18] http://leg1.state.va.us/081/bud/budsum/bud30a.pdf

As discussed earlier, the industry model has the focus of generating research results and enhancing the commercialization of those results.

4.2.1 California NanoSystems Institute

The California NanoSystems Institute was established in 2000 with $100 million from the state to create this program as one of the four Governor Gray Davis Institutes for Science and Innovation. With an additional $250 million in federal grants and private investment the initiative has centers working collaboratively at both the University of California at Los Angeles and the University of California at Santa Barbara with its industrial partners, including Intel, Hewlett-Packard, Amgen, Sun Microsystems, Oracle, BASF, and Abraxis.[19] [20] With the massive initiatives in the state for biotechnology and stem cell research a significant portion of activities are directed towards bio-nanotechnologies.

The main focus is to establish solid relationships with industry as a means of accelerating technological innovations. Other significant interests of the center are to encourage research in, and commercialization of, biomedical and manufacturing applications, to train nanoscale researchers, to generate public support, and to promote development of this and related advanced technologies in California. It also has a series of websites (http://www.cnsi.ucla.edu/ and http://www.cnsi.ucsb.edu/), seminars, news bulletins, and a platform to connect with researchers in the centers. Having a mission that also includes educational and outreach components some of the space in the facilities was dedicated to large theater-style lecture halls and presentation space.

In addition to the aforementioned push for advancement in biotechnologies, stem cell advancements, and environmental technologies the state of California has many research laboratories and groups across the university

[19] http://www.nsti.org/nanotech2007/sponsors.html?id=80
[20] http://www.ucop.edu/california-institutes/partners/cnsi.htm

system, and even in federal laboratories operated by the university system, that are actively pursuing areas of interest in nanoscale science and engineering in a simple decentralized manner.[21] There are also partnerships across universities with the Ames Research Center, as operated by the National Aeronautics and Space Administration.[22] Furthermore, there are vibrant local initiatives such as in the San Francisco Bay Area and in Southern California. There is also no shortage of collaborations among these networks or with the California NanoSystems Institute centers to make fruitful use of the established infrastructure. Furthermore, there is a vibrant system of assistance for business development and advanced technologies from the California Economic Development Partnerships, the California Economic Leadership Network, and the California Infrastructure and Economic Development Bank whose support is not specifically for nanotechnologies.

4.2.2 New Jersey Nanotechnology Consortium

The New Jersey Nanotechnology Consortium was created in August of 2002, and fully established as a non-profit organization and wholly owned subsidiary of Lucent Technologies (now Alcatel-Lucnet) by April 2003.[23] [24] The support of the state of New Jersey, as well as the New Jersey Institute of Technology and federal support of $2 million each, was pledged to help further the development of commercial nanotechnologies through cost-effective new designs, shorter-time prototyping, and advanced production capabilities in New Jersey.[25] The main site is within the existing Bell-Labs-operated, Alcatel-Lucent-owned, New Jersey Nanotechnology Laboratory facility in Murray Hill. There is additional support through the National Science Foundation, the University of Medicine and Dentistry of New Jersey,

[21] http://www.universityofcalifornia.edu/research/nanotech.html
[22] http://www.watechcenter.org/downloads/california.brtfn.pdf
[23] http://www.njnano.org/about/milestones.shtml
[24] http://findarticles.com/p/articles/mi_m0EIN/is_2003_April_1/ai_99455507
[25] http://www.smalltimes.com/articles/stm_print_screen.cfm?article_id=268053

and Rutgers University as well as projects supported by Pfizer, the U.S. Army, and the Defense Advanced Research Projects Agency.

The focus of the organization is to first ease the transition of new nanotechnology applications to current marketable products. The benefit to using an existing facility was mentioned to be being able to use resources for advancements instead of having to invest $150 million into just the facilities. There is also a push for the center to maintain an internet presence (http://www.njnano.org/), create new lines of business into the nanotechnology sector through commercialization, to increase government support and investment into its operations, and to increase the cooperation and productivity of the existing advanced basic research in nanotechnologies taking place within the state. The center is working on projects for pharmaceuticals, biotechnologies, medical, chemical, environmental, defense, materials, semiconductors, optics and photonics, aerospace, energy, and telecommunications all from their ties to nanotechnology applications. The hope is that the focus of the center itself on commercialization activities will free the researchers to broaden the spectrum of potential application fields, to be more interdisciplinary, and to generate novel discoveries.[26] There is a sense of a continuum from wide-ranging research to highly-focused commercialization with their recognition of having claim to winning several Nobel prizes at the same time as filing patents and finishing products.

4.2.3 New York Loves Nanotech

The New York Loves Nanotech initiative has been around in some form since 2000 after Governor George Pataki partnered with IBM Inc. to establish the $2.5 billion microchip plant in East Fishkill, New York. Their relationship was furthered with the help of IBM's $100 million in establishing the Center for Excellence in Nanoelectronics and Nanotechnology at the State University of New York at Albany to accompany the state's $50 million investment. The center records having over $5.8 billion in investments

[26] http://findarticles.com/p/articles/mi_qa5438/is_200507/ai_n21376643

(nearly $1.05 billion of it being state support) with 11 nested centers and four state-of-the-art research facilities on site.[27] There has been support from other industrial players such as SEMATECH, Tokyo Electron, Advanced Micro Devices, Applied Materials, Vistec Lithography, ASML, and Einhorn Yaffee Prescott, which include relocations if not expansions to their presence in the region.[28] There have also been established relationships with researchers at centers from other universities such as the near-by Rensselaer Polytechnic Institute, as well as Clarkson University, Columbia University, Cornell University, and the State University of New York at Binghamton within the state and several outside of New York.[29] [30]

The activities at the center include research and training from the faculty and students within the College of Nanoscale Science and Engineering at the university, as well as active research and commercialization activities by the numerous corporate researchers. Having nested centers for semiconductors, nanomaterials, nanoelectronics, lithography, and fabrication at the same location as some of the leading companies engaged in those ventures provides for a synergistic and efficient melding of discovery and technology transfer. The educational programs include graduate-level (Master of Science and Doctor of Philosophy) degrees in nanoscale science and nanoscale engineering, and have optional components that allow for a dual completion of a Masters in Business Administration. The undergraduate program allows student to study in one of four "constellations" within the school: nanoscience, nanoengineering, nanobioscience, and nanoeconomics. The center maintains a rather extensive website at http://cnse.albany.edu/.

New York has additional programs that focus their "love" on business and high tech. Empire State Development, the state's economic development corporation, takes the opportunity to provide business assistance, incubators,

[27] http://cnse.albany.edu/about_cnse/quick_facts.html
[28] http://cnse.albany.edu/about_cnse/history.html
[29] http://www.nystar.state.ny.us/cats.htm
[30] http://albany.bizjournals.com/albany/stories/2008/02/18/daily6.html?t=printable

Empire Zones for development, and Centers for Advanced Technology apart from nanotechnology. These efforts have promoted growth in research and development for electronics, life sciences, environmental systems, manufacturing assistance, advanced materials, biotechnologies, optics and photonics, and software and information technologies. Some of these initiatives have been directed with help from the New York State Foundation for Science, Technology, and Innovation, which is the public authority that helps manage the strategic direction of New York's innovation economy.

4.3 University Models

Based on the findings of the study two of the state's initiatives are being classified as belonging to the university model: Illinois and Oregon. The placement is based upon the extensive reliance upon researchers in the universities to drive the initiative, the cooperation require among the researchers to make progress across different universities and federal laboratories, and due to the inclusion of educational training for researchers and students. As was noted earlier the focus of the university model is to generate research activities, to commercialize potential advances, and to educate the next generation of researchers and practitioners of nanoscale science and engineering.

4.3.1 Illinois Coalition

The Illinois Coalition was established in 2003 to promote the development of research infrastructure in advanced technologies within the state of Illinois. The group is a public-private partnership, drawing annual support of $0.75 million annually through the state's Department of Commerce and Economic Opportunity. In addition to some limited private investment, the main actors in the coalition are the researchers in universities as well as federal laboratories in the state. The coalition has garnered state support of over $63 million since 2001 for support to nano-specific facilities.[31] It might also be confusing to distinguish this coalition from the previous described

[31] http://www.watechcenter.org/downloads/ni_otherstates.pdf

consortium models, but I would argue that although they do lobby for more support like a consortium they do have established infrastructure and also provide and direct funds to research projects. Many of the advocacy efforts have proven beneficial as three of the seven Illinois Research and Technology Parks have nanotechnology capabilities (Skokie, University of Illinois at Urbana-Champaign, and Illinois Institute of Technology).[32] In addition, there are five designated nanotechnology research programs from the university system as well as private institutions like the University of Chicago and Northwestern University.[33] Besides the James Franck Institute, the Beckman Institute for Advanced Science and Technology, and the International Institute for Nanotechnology there is also work with the Argonne National Laboratory, Fermi National Accelerator Laboratory, and the National Center for Supercomputing Applications.[34] [35]

The base of Illinois for nanotechnology comes from its exposure to AtomWorks in 2002. The regional private consortium was meant to boost enterprise development in nanotechnology, and has since morphed into the national advocacy organization the NanoBusiness Alliance which has established a firm presence in Washington, D.C.[36] From this initial work, further establishments within the state have taken hold of promoting the work done in nanotechnology and has been working to help create prominent research, to encourage commercialization through the technology transfer offices of the university system, and have push for specialize programs within the universities for nanoscale proficiency and focus.

The state also has a large amount of resources available for other emerging technologies such as biotechnology, advanced genomics, targeted medicine, advanced agriculture, advanced semiconductors, supercomputing, and

[32] http://www.iltechparks.com/
[33] http://www.illinois.gov/tech/nanotechnology.cfm
[34] http://www.commerce.state.il.us/dceo/print/default?uid={3A4903BE-EFFA-4B13-B8C 4-189A21DE4C58}
[35] http://www.iltechparks.com/randd.htm
[36] http://www.atomworks.org/about.php

advanced materials to name a few. With these other opportunities for innovation there also becomes a more competitive environment for resources but at the same time a more cross-disciplinary approach to better leverage those resources.

4.3.2 Oregon Nanoscience and Microtechnologies Institute

The Oregon Nanoscience and Microtechnologies Institute was created in 2003 with federal support as a signature research center under the Oregon Innovation Council. This should not be seen as an agency model for the activities performed by the Oregon Innovation Council are meant to be advisory, and like an advocate, as opposed to managerial. The actions of the state are still required and the administration of the activities takes place with the work of the researchers and partners. Since then the state has invested over $21 million dollars to augment the national support of almost $100 million.[37] The center has established relationships for research activities, educational activities, and government support. The center has connections with Eastern Oregon University, the Oregon Health and Science University, the Oregon Institute of Technology, Oregon State University, Portland State University, Southern Oregon University, the University of Oregon, and Western Oregon University, as well as the Pacific Northwest National Laboratory. Additionally, primary and secondary school outreach is performed with the assistance of the Oregon Museum of Science and Industry.[38] The center has also reach-out to industrial partners in the area such as Hewlett-Packard, Intel, Pixelworks, and some twenty others.[39]

The center has a focus on performing research, developing products, and educating students in Oregon. The activities include creating applications in energy and chemical systems, advanced manufacturing, nanolaminates, advanced semiconductors, and other nanomaterials. There are also efforts to recruit talented researchers and industry partners as well as developing nano-

[37] http://www.oregoninc.org/initiatives.htm
[38] http://www.onami.us/community/
[39] http://www.oregoninc.org/07plan/ronami.htm

specific educational programs for the K-12 students and higher education. It also hosts a website with interactive learning features and contact resources (http://www.onami.us/). The hope is that the work will produce benefits to the people and businesses in the area.

The Oregon Innovation Council has also suggested the establishment of additional research centers for other innovation sectors, and the state has put together resources for emerging technologies and business development in general. The additional activities for life sciences, medicine, and environmental sciences could be seen to be additional avenues for collaboration and growth in the nano-related field.

4.4 Agency Models

From the selection of states there are two that are being labeled as having an agency model: Massachusetts and Pennsylvania. The classification is based upon the independent operation of the initiative, and that the policy mix with which to achieve the goals of the initiative is left to the governing agency to determine. As was mentioned, the main focus of the agency model is to achieve through autonomy.

4.4.1 Massachusetts Nanotechnology Initiative

The John Adams Innovation Institute was established within the Massachusetts Technology Collaborative in 2004 as part of the state economic stimulus bill. The Massachusetts Technology Collaborative is the state's non-profit technology-based economic development agency, which has been given the authority over the Innovation Institute Fund and the Massachusetts Research Center Matching Grant Fund to administer projects for wireless learning, advanced health technology, and nanotechnology. The initial state support was $15 million for the regional initiatives, $20 million for enhance funding to research at universities and non-profit institutes, and more than $26 million for emerging technologies and technology transfer

programs.[40] [41] The 2006 state economic stimulus package included nearly another $30 million for initiatives within the innovation initiatives as well as $20 million for a new facility for the Nanomanufacturing Center of Excellence at the University of Massachusetts at Lowell (which was created out of a $5 million award from the 2004 appropriation).[42] This is all organized under an operating budget averaging about $0.5 million annually.[43] It is important to note that the bulk of these funds is not meant to be used for nanotechnology projects exclusively, but it is the key focus for further development in 2008 according to the Massachusetts Technology Collaborative.[44]

The focus of the efforts for the Massachusetts Nanotechnology Initiative includes promoting collaboration of researchers across institutions, sectors, and clusters, developing research centers, making strategic investments in infrastructure and incubators, and convening policymakers with stakeholders in academia and industry throughout the state. The initiative has identified over 100 nanotechnology firms in the state, and determined a critical mass of existing industries in supporting and collaborative sectors such as biotechnology, pharmaceuticals, medical devices, and semiconductors.[45] There has also been support to the National Nanotechnology Initiative centers like the Institute for Soldier Nanotechnologies at the Massachusetts Institute of Technology, the Science and Nanoscale Systems and their Device Applications Center at Harvard University, and the Nanoscale Science and Engineering Center between the University of Massachusetts at Lowell, Northeastern University, and the University of New Hampshire. There is additional collaboration across Boston University, Boston College, Tufts University, Worcester Polytechnic Institute, and the University of Massachusetts at Amherst. An interesting aspect is that the space for the

[40] http://www.mtpc.org/agencyoverview/history11-05.pdf
[41] http://www.masseconomy.org/html/9_3admin_aboutus.html
[42] http://www.uml.edu/nano/about_us/history.html
[43] http://www.mass.gov/bb/gaa/fy2009/prnt_09/app_09/act_09/p70071200.htm
[44] http://www.mtpc.org/agencyoverview/mtc2007annualrpt7.pdf
[45] http://www.mtpc.org/mni/index.htm

Massachusetts Technology Collaborative is part of a former microelectronic research center, and the facilities and support buildings on the campus are leased-out to companies as part of the technology incubator program.

The state has goals for nanotechnology to include job production, workforce development, educational programs, and assistance for regional innovations that have yet to be further deployed.[46] Still, the prospect for further development is likely. The other initiatives in the state to promote other emerging technologies and to enhance existing industries are good practices to help assist advances in the state overall, and in nanotechnologies specifically.

4.4.2 Pennsylvania Initiative for Nanotechnology

The Pennsylvania Initiative for Nanotechnology was established for 2006 to be administered by the Ben Franklin Technology Partners, a public corporation created to help promote economic development and establish partners in existing industries for innovations. The initiative was put forth with about $15 million in annual state support, with nearly $4.5 million from private and federal funds.[47] The money is to promote research endeavors at Carnegie Mellon University, Drexel University, Lehigh University, the Pennsylvania State University at College Park, the University of Pittsburgh, and the Nanotechnology Institute at the University of Pennsylvania. Some of the initiative was to support workforce development programs across the community college system, nanomanufacturing programs, and commercialization efforts within the state. What is interesting in this case is that these activities were already occurring and were simply refashioned into a single initiative for nanotechnology as opposed to coming from efforts to promote advanced manufacturing or workforce development.

[46] http://www.masstech.org/institute/research/nano2004_3_1.pdf
[47] http://www.ed.psu.edu/cshe/nano/Papers/Nanotechnology_and_the_States.pdf

The focus of the initiative is to build from the established base of nanotechnology education and training to promote collaboration across institutions for research and to increase commercialization of nanotechnology applications including enhanced university-based resources for technology transfer.[48] Further there is a hope to introduce nanoscale concepts into science, technology, engineering, and mathematics education, to produce well-trained nanoscientists, and to establish relationships with industry to provide students with experience in characterization, fabrication, and manipulation techniques. Efforts are made to incorporate nanotechnologies across manufacturing, materials, pharmaceuticals, and chemical companies with the hope that it will also affect electronic, energy, environmental, medical, and consumer sectors.

The state has initiatives in other industries such as information technologies, biosciences, manufacturing, and telecommunications. There is also a series of technology-based economic development partners for these initiatives like the Idea Foundry, the regional Life Sciences Greenhouses, the Technology Collaborative.[49] Pennsylvania also has a series of Small Business Development Centers and Keystone Innovation Zones to foster new ventures in emerging technologies.

4.5 Roadmap States

From the study the results have four states being denoted to be roadmap states: Colorado, Minnesota, North Carolina, and Washington. This is outside of the model structure devised through this study, and these states are those that were investigated and were determined to have a state-level strategy that either has not received authorization, has not received any budgetary support, or is simply not yet implemented. These states should be kept in mind in addition to previously mentioned states as those from which lessons can be devised when fashioning an initiative in the future.

[48] http://www.newpa.com/default.aspx?id=56
[49] http://www.newpa.com/default.aspx?id=299

4.5.1 Colorado Nanotechnology Roadmap

The Colorado Nanotechnology Roadmap was published in 2006 in response to the efforts of the Colorado Nanotechnology Alliance.[50] The alliance would be appropriate to consider for an initiative for the consortium model if it were not for the lack of a tie to the state through policy. The alliance is a private non-profit organization which seeks to promote nanotechnology research, commercialization, and industrial growth within Colorado, and has made ties to the national NanoBusiness Alliance.[51] There was also some assistance in garnering a $12 million strategic fund to seed nanotechnology start-ups.[52]

The roadmap was put together through the Leeds School of Business at the University of Colorado at Boulder. There was also support for the project from the Colorado Office of Economic Development and International Trade as well as the Office of the Mayor of Denver and the United States Department of Commerce. Public and private interests were also captured in the Roadmap Advisory Task Force with business and education leaders. There is a hope that the initiative moving forward will work to coordinate research activities, to promote workforce development programs, and will push for continued business growth.

With the demonstrated desire to include research facilities, workforce development, and educational programs the goals would be to reach what would constitute the university model. Fitting with a few research universities and some federal facilities in the area this would seem to be an appropriate fit for Colorado.

4.5.2 Minnesota Nanotechnology Initiative

[50] http://www.coloradonanotechnology.org/home/images/stories/pdf_and_ms_word_docs/nanoroadmap_final.pdf
[51] http://www.coloradonanotechnology.org/home//index.php?option=com_content&task=view&id=13&Itemid=26
[52] http://www.watechcenter.org/downloads/ni_otherstates.pdf

The Minnesota Nanotechnology Initiative started in 2006 and is based largely on the work of an alliance, MN Nano, to promote the state's assets in nanotechnology for Minnesota's competitiveness.[53] The group is composed of private industry, service providers, higher education institutions, and government agencies but with no found linkage to state policy-making. The alliance works to promote business development, and to advocate for increased investments in nanotechnology infrastructure, research, commercialization, and education.

The initiative has put forward proposals to achieve these goals which have not been approved by the state legislature and thus is still working on establishing a more certain initiative. The state has seen investments in the university system for research activities from the national level and includes the placement of the University of Minnesota as part of the National Nanotechnology Infrastructure Network. Looking to leverage these investments would generate a university model, noting also that proposals from MN Nano include having a strategic fund to bolster nanotechnology start-ups similar to the actions in Texas and Colorado.

4.5.3 Roadmap for Nanotechnology in North Carolina

Since 1998, there have been several research universities in North Carolina that have participated in the joint consortium called the North Carolina Center for Nanoscale Materials, although the vast majority of the monetary support has been drawn from the federal level through the Office of Naval Research Multidisciplinary University Research Initiative.[54] Still, the North Carolina Board of Science and Technology has helped establish a concerted initiative for biotechnologies, and has helped direct tens of millions of dollars in state support for facilities and research. In 2005 the state's Advisor for Science and Technology in the North Carolina Department of Commerce

[53] http://www.mnnano.org/
[54] http://www.watechcenter.org/downloads/ni_otherstates.pdf

joined with the board to form a task force to produce a roadmap for nanotechnology.[55]

The 2006 report was released calling for an increased degree of coordination of research activities, to provide a supporting public and political environment, to establish an investment capital fund, to align research to demonstrated industrial needs, to develop educational and workforce training programs, and to partner in a cross-cluster initiative with the advanced materials, biotechnology, and information technologies. There is also a push to create additional state incubator efforts as well as to promote company and job growth over commercialization.

With all of the efforts and successes of the biotechnology initiative through the university centers, it seems that the roadmap is directly for a similar university model to be employed for nanotechnology.[56] With the prominence and productivity of the research triangle it would seem appropriate to suggest such a method of operation.

4.5.4 Washington Nanotechnology Initiative

The Washington Nanotechnology Initiative was released in 2005 by the Washington Technology Center, the state's technology-based economic development organization.[57] The report was created with the assistance of the private firm the Avogadro Partners, with an eye to boosting the innovation economy in Washington with advanced in nanotechnology across the many existing industries such as agriculture, energy, electronics, aerospace, life sciences, telecommunications, software, and information technologies. Facing competition in the region from California and Oregon, the state felt it appropriate to push forward with nanotechnology efforts. The research in the university system achieves federal support, and there is membership for some of those centers in the collaboration consortium

[55] http://www.ncnanotechnology.com/public/_assets/NCNanotechTaskForceReportFinal.pdf
[56] http://www.ncbiotech.org/resource_center/documents/nanotech_report.pdf
[57] http://www.watechcenter.org/downloads/nanotech_reportfnl_011005.pdf

through the Pacific Northwest National Laboratory called the Northwest Nanoscience and Nanotechnology Network.

The initiative is calling for greater collaboration in research, to expand infrastructure, to develop early-stage capital, and to increase educational programs. There was a demonstrated desire to promote the university research to generate start-ups, citing within its argument the point that 63% of ventures started out of universities since 1980 were still in operation and that 83% of them remain in the state from which they were created. Seeing as there was a noted push for business development funds, and a reliance upon the Washington Technology Center for support, it seems as though this initiative would fall under the agency model. The proposal also calls for increased use of university and federal laboratories and a dedicated effort to recruit high-profile nanoscale science and engineering researchers to those centers. The ultimate end result is to have all of the cutting-edge efforts building across the established industries in a coordinated fashion to establish the pacific northwest as the leader in nano. There are efforts in Washington already working such as business development programs, research facility expansions, and educational program creation through the state's Department of Community, Trade, and Economic Development and the Washington Economic Development Association.

4.6 No Official Action

Based on the research there are three states that are not being classified: New Mexico, Tennessee, and Wisconsin. State might not fit the criteria for characterization due to having no activity in nanotechnology, no official state-level policy, or no specific inclusion of nanotechnology into its initiatives. The following highlights some of the efforts in nanotechnology but does so in limited detail due to the scope of the paper.

4.6.1 New Mexico

Within New Mexico there is the Micro and Nanotechnology Commercialization Education Foundation whose purpose is to provide a forum for the exchange and furthering of information between researchers and developers, to promote start-up companies, and to advocate for increased support for research and commercialization activities for New Mexico companies.[58] This is quite similar to the consortium model that was presented earlier with the exception of no official state policy action to be linked to the group. There is involvement from the Office of the Mayor of the City of Albuquerque and private firms, as well as links to the Sandia National Laboratories. Los Alamos National Laboratory is also active with Sandia in the Center for Integrated Nanotechnologies, which is supported also by the Lockheed Martin Corporation.[59] New Mexico has been looking to improve upon its infrastructure through its university system and to harness the advancements of the nano-related industries that have been growing within the state.

4.6.2 Tennessee

Tennessee has the Oak Ridge National Laboratory facility as well as the public-private group the Innovation Valley Nano Alliance working on developing the nanotechnology sector within the state.[60] Still, the focus of the effort is on working within the eastern part of the state, and although has the support of the University of Tennessee it is not a state-wide initiative. The work of the alliance also joins with other consortia that look to enhance the infrastructure, bolster research activities, acquire research talent, and to build business support.[61]

4.6.3 Wisconsin

[58] http://www.mancef.org/nnnm.htm
[59] http://cint.lanl.gov/about.shtml
[60] http://www.nanovalley.us/about_us/index.html
[61] http://www.tech2020.org/history.htm

The state of Wisconsin is looking to partner with the state of Minnesota and the state of Illinois to establish an I-Q Corridor for technology innovation.[62] Having prepared the Wisconsin Technology Council and the Wisconsin Venture Center to build efforts towards increased biotechnology and advanced manufacturing programs like its neighbors, it seemed likely that there would have been a developed strategy for nanotechnology within Wisconsin as well but the study did not yield any results to suggest such. There have been some state allocations for biotechnology and biomedical facilities that have had a nanotechnology focus if not a component. Still, the overall efforts specifically for nanotechnology seem absent. Nonetheless the state has established business support and workforce development programs for some other innovation sectors and has put together an extensive network of capital seed funding through the Wisconsin Angel Network. Additionally there is a group of university researchers who have assembled a consortium for security and homeland defense research innovations and ideas. Wisconsin has also put forward a program to grow the state through grants to innovation in biotechnology and manufacturing as well as to encourage more technology transfer. Lastly, the university system has put together a Nanotechnology Research Laboratory at the University of Wisconsin at Milwaukee and University of Wisconsin at Stout has developed a nanoscale curriculum through its bachelor degree in Applied Sciences.[63] [64]

[62] http://www.wisconsintechnologycouncil.com/i-q_corridor/
[63] http://www.uwm.edu/people/nkouklin/index1.htm
[64] http://www.uwstout.edu/programs/bsas/bsas_ppnano.pdf

5.0 Best Practices

The following section brings forth the ideas highlighted from the investigation of the selected states as they are focused to achieve particular objectives within the goals of the nanotechnology initiative in general. The practices are pulled from both from the states with a decided state-level initiative as well as those that were not categorized with the intent of presenting the ideas generated by others as a way to address the situation. The section is divided by the four overarching goals as mentioned in Section 3.2 to cover the methods to promote up-stream nanoscale research activities, promote down-stream nanoscale research activities, translate nanoscale skills, and generate economic activity.

5.1 Up-Stream Research Activities

Up-stream research activities are referring to the general purpose, and minimally use-inspired research activities that take place in the laboratory setting with the hope of gaining knowledge that may or may not have specific applications. The activities in this area that are being employed for nanotechnology include lobbying for infrastructure, partnering with centers to make use of infrastructure, connecting researchers for research, aligning research centers toward industrial needs, having a dedicated fund for research allocations, and recruiting research talent to centers.

To have the ability to perform research at the nanoscale there is a need to have the appropriate space and equipment. This was brought about with the efforts of researchers and consortia being active in government lobbying. The development of infrastructure is an important component to advances in this area, and the activities in Arizona, Colorado, Massachusetts, Minnesota, New Mexico, Oregon, and Texas demonstrate the efforts to lobby for more developments in infrastructure. Partnering with other centers to make good use of infrastructure developments improves the usage of the facilities and fosters further inquiry. This was accomplished through official partnerships as well as connections through various consortia. The partnering with other institutions is a part of the efforts in California, Colorado, Illinois, Massachusetts, Minnesota, New York, Oregon, Pennsylvania, Virginia, and Washington. Connecting nanoscale researchers with each other allows for a dialog and exchange of ideas between those active in the field to the effect of

generating new ideas and spreading methods. This was done through websites, e-mails, conferences, and consortia. Bringing researchers together is an important aspect in Arizona, Colorado, Illinois, Massachusetts, Michigan, New Mexico, North Carolina, Oregon, Texas, and Virginia. Aligning research centers towards industrial needs encourages the inclusion of private firms within the research activities to increase the acitivity and create greater informational exchanges. This was achieved by partnering with industry to share in costs for construction with the exchange of space within, and sometimes near-by as well, the center. Including industrial needs is part of the goals in New Jersey, New York, North Carolina, Oregon, and Texas. Having a dedicated fund for research initiatives allows for a competitive process by which activities within a state are vied for with the hope of encouraging discovery in that state. This is accomplished with the creation of research grants funds, matching grant funds, or innovation promotion seed funds. Dedicated funds for research are included in Illinois, Massachusetts, Minnesota, North Carolina, Texas, and Washington. Having well respected researchers in nanoscale science and engineering allow for the programs of research and education performed build programs and centers that will reflect that reputation. This is accomplished by recruiting excellent faculty to university research centers to produce discoveries and the next wave of researchers. Seeking eminent researchers is part of the plan in Oregon and Washington, as well as currently already in Georgia.

5.2 Down-Stream Research Activities

Down-stream research activities are referring to the use-inspired and commercialization activities that surround development of research products. The ways in which this area has been advanced was seen through the inclusion of industry within the research centers, by leveraging the resources within the technology transfer offices within the university center partners, having start-up development funds, and promoting regional clustering.

To make a fruitful use of the knowledge generated through research activities there have been those who have partnered with the industries that are apt to use the knowledge generated in the products in produces. This is accomplished by including

the industries in the research center by allowing their researchers to participate in activities with the public researchers involved in the work. Including industry in the center is part of the plans for California, New Jersey, and New York. Using the technology transfer offices at universities promotes the application of knowledge generated by university researchers for liscensing. This is accomplished by establishing relationships with universities and bolstering their technology transfer offices with those who understand the potential for nanotechnologies. Technology transfer office use is prominent in Colorado, Illinois, Michigan, Oregon, and Virginia. Promoting start-ups allows those who have generated new knowledge to put it to use in a new private venture. This is accomplished by having seed capital funds available for innovation firms. Start-up development is part of the work done for Colorado, Massachusetts, New Mexico, North Carolina, Washington, and Wisconsin. Allowing for regions within the state to develop clusters helps put the local resources and needs to adapted use for development. This is accomplished by having regional divisions to the initiative, having specialized zones, or allowing the agency to specialize in regions. Regional sectors are part of the efforts in Massachusetts, New York, North Carolina, Pennsylvania, Tennessee, Texas, and Washington.

5.3 Translating Skills

Translating skills is referring to the development of the population for the use of the nanotechnologies developed. The methods by which this goals was achieved was through creating workforce development programs, teaching nano-specific degree programs, and informing the general public through outreach activities.

Having workforce development programs allows those that are involved in industry to augment their training by being taught in the techniques to use the equipment and processes affected by the innovation. This is accomplished by creating programs at two-year colleges and technical colleges to train those that are to use nanotechnology or are to produce nanotechnologies. Workforce development programs are a component in Colorado, North Carolina, Pennsylvania, and Virginia. Offering nano-specific degrees allows for in-depth education and research training for the next

wave of nanoscale scientists and engineers. This is accomplished by providing concentrations of degrees and full degrees within higher and advanced education programs. Nano-specific programs are utilized in California, Colorado, Illinois, New York, Washington, and Wisconsin. Having general public information and outreach allows for a practical perspective and a demystifying of nanotechnology so that there will be less panic and more interest in its exploration. This is accomplished through positive public relations, public service announcements, and programs that are directed towards those in primary and secondary education levels. Outreach is part of the work laid-out for California, North Carolina, Oregon, and Pennsylvania.

5.4 Economic Activity

Economic Activity is referring to the boost to the overall area and economy of the area where the innovation in nanotechnology comes from. By area this is connecting the development to the region, state, and nation that emerges as the leader of the emerging technology. This has been best demonstrated to happen with a rapid turn-around in sectors that involve previous high-technology advancements. By leveraging established technology-based firms within the area will hopefully be equipped to handle a new technological innovation again. This is accomplished by utilizing information technologies, advanced materials, semiconductors, biotechnologies, medical devices, or environmental technologies. Using high-technology industries are included in California, Massachusetts, New Jersey, New York, North Carolina, Pennsylvania, Texas, Virginia, and Washington.

6.0 Outlook

This section is about the work performed and what it means. There is to be a discussion of the implications of this work for Georgia, what should be focused upon for later study, and a disclosure of those involved in this project.

6.1 Challenges for Georgia

When considering the application of the methods employed by other states to achieve the goals for nanotechnology development there are some important considerations that should be noted about what to overcome in the current situation to make beneficial use of the suggestions contained herein. When looking to up-stream research activities most of the activity is concentrated in the Atlanta metropolitan region, and to foster partnerships and develop infrastructure it tends to be helpful to have regional dispersion and well established working relationships. This can be overcome with many partnerships and the further cultivation of a nanoscale infrastructure in other regions of the state such as Swainsboro. When considering the down-stream research activities there is a general lacking of private research and development in Georgia and few incentives to innovate within the existing industries of the state being that they are more traditional. When hoping to broaden the translation of skills there is the potential for a public push-back similar to the one experienced with the recent work in biotechnologies. Additionally, the state resources in nanotechnologies will need to have a broad focus of nanoscale science and engineering and this will be assisted by the establishment of multiple, and differentiated, centers. Lastly, the base of traditional industries is not only prone to less research but its markets are well established and are not easily positioned for vast growth from the development of high-technologies. With these hurdles in mind there can be a careful consideration of the next steps to be taken in Geogia to learn from the states profiled in this study.

6.2 Recommendations for Georgia

Based on what is characterized as part of the Georgia landscape in nanotechnologies, and the results found from looking into other states' efforts to develop nanotechnologies, it seems appropriate at this time to recommend the following

series of actions to be taken on the near-term and on the long-term. The purpose of these recommendations is to more fully develop the nanotechnology landscape in Georgia and to help compete to be a leader in parts of the nano sector.

6.2.1 Near-Term Activities

When considering the near-term, this is referring to a period of time to have accomplished these goals from three to five years. These would be the easiest to implement, and would be aligned well with the current status of the state. There should first be the creation of a nano-related association with public and private partners. This step is similar to creating a consortium model within Georgia. The goal would be to get researchers and policy-makers to become informed about the activities going on around the state, and to lobby for the next series of recommendations. There should be a concerted effort to update and expand the current technology transfer offices and the Eminent Scholars programs to include nanotechnology specifically as a primary focus. This would involve providing money and staff to the universities to research the emerging nanotechnology markets and providing more support to the Georgia Research Alliance to continue bringing star researchers to the university system. This consortium should then turn its efforts to developing further partnerships for research and development as well as to establish more and expand existing research facilities to accommodate the growth in the nanotechnology demand. By lobbying the private firms, the state, and the federal level there could be effective awarding of resources to enhance the infrastructure for nanoscale research. Lastly, the consortium should push for the creation of, and subsequently the best use of, dedicated funding accounts for nanotechnology innovation research as well as nanotechnology start-up ventures. By having a state-level competitive pool of resources to assist these projects there will be an incentive to establish and manage efficient resource management as well as new partners to collaborate on research, as well as a gap to aid the transition from new idea to a market presence. These are building blocks to future developments.

6.2.2 Long-Term Activities

When considering the long-term, this is referring to initiative that would take more than five years to develop and implement. These are among the larger goals and are end results to establishing a role as a leader in nanotechnology. The goal would be to transition to a more developed model as was outlined in this study. Presuming the change is to an industrial model, if possible, it would require the creation of a new center to align with an established industry that is looking to innovate. This would involve the incorporation of activities from a traditional industry (such as manufacturing, agriculture, textiles, or paper) to a research facility to investigate nano-enabled advances. This would also work to promote others in this industry to relocate to this research center or its surrounding area. A more natural transition would likely be to a university model, in which university centers link together to boost the state. There would then need to be the development of a workforce development program for manufacturing throughout the two-year and technical colleges. In addition there should also be the development and launch of nano-specific degree programs at the university level to train more researchers. For this growth in educational components there would have to be a dedicated effort to raising the achievement marks in the Science, Technology, Engineering, and Math disciplines in the primary and secondary education levels in the state to allow for the home-grown student to excel in nano-specific programs. Should there be enough of a development of nanotechnology in the state it would be wise to shift to an agency model to monitor the continued growth and adjust the policy mix to match demand. A department or agency to recommend the allocations from the development and research funds, or to help coordinate research initiatives across institutions, or to recruit researchers and industries would allow for the most developed model of nanotechnology policy. This agency would also then be able to suggest additional changes, or modify the existing structure to accomplish maximum growth.

6.3 Further Investigation

At the conclusion of this study it would be appropriate to identify the topics that would come next as an area for investigation besides considering studying the remaining states within the country. There should be future consideration of the overall growth from nanotechnology initiatives to see which prove most beneficial, for isolating the best state of the best model would be helpful for other states as well as the nation. There should be consideration of the effect of having additional innovation clusters and research initiatives for it can be difficult to isolate the effects of a large amount of resource being put to use in one powerful state versus the additional benefits to competition and cross-collaboration as w means of driving innovation. Lastly, it should be investigated how to set clear policies for research in multidisciplinary fields such as nanotechnology. Knowing how to regulate and educate for such a sector as nanotechnology will require many methods and modes of thought, which can be difficult to reconcile within the policy context.

6.4 Acknowledgements

Support for this work came from the Enterprise Innovation Institute. I would like to thank the staff there, including Professor Jan Youtie, Robert Lann, Terry Gandy, Joy Hymel, and Hazel Taylor. Additionally I would like to acknowledge the assistance of Professor Philip Shapira from the School of Public Policy, and Dr. James Meindl and Gregory Book of the Microelectronics Research Center.

7.0 References

In addition to the cited reference sources there was heavy usage of the information contained in the following reports from the National Nanotechnology Initiative

1. National Nanotechnology Initiative: The Initiative and its Implementation Plan, NSTC/NSET Report, July 2000. http://www.nano.gov/html/res/nni2.pdf
2. The National Nanotechnology Initiative Strategic Plan, December 2004. http://www.nano.gov/NNI_Strategic_Plan_2004.pdf
3. National Nanotechnology Initiative Strategic Plan, December 2007. http://www.nano.gov/NNI_Strategic_Plan_2007.pdf
4. Regional, State, and Local Initiatives in Nanotechnology, Report of the National Nanotechnology Initiative Workshop, September 30-October 1, 2003. http://www.nano.gov/041805Initiatives.pdf