Regional, State, and Local Initiatives in Nanotechnology

Report of the National Nanotechnology Initiative Workshop

May 1–2, 2012

Portland, Oregon

About the Nanoscale Science, Engineering and Technology Subcommittee

The Nanoscale Science, Engineering and Technology (NSET) Subcommittee is the interagency body responsible for coordinating, planning, implementing, and reviewing the National Nanotechnology Initiative (NNI). NSET is a subcommittee of the Committee on Technology of the National Science and Technology Council (NSTC), which is one of the principal means by which the President coordinates science and technology policies across the Federal Government. The National Nanotechnology Coordination Office (NNCO) provides technical and administrative support to the NSET Subcommittee and supports the subcommittee in the preparation of multi-agency planning, budget, and assessment documents, including this report. More information about the NSET Subcommittee, the NNI, and NNCO can be found at http://nano.gov.

About the National Nanotechnology Initiative

The NNI is the Federal nanotechnology R&D initiative established in 2000 to coordinate Federal nanotechnology research, development, and deployment. The NNI consists of the individual and cooperative nanotechnology-related activities of 27 Federal departments and agencies that have a range of research and regulatory roles and responsibilities. The NNI's member agencies are committed to involving the full spectrum of stakeholders in development of responsible and forward-looking U.S. R&D and regulatory programs with respect to nanotechnology advancement.

About this document

This document is the report of a workshop held 1–2 May 2012. It is the fourth in an ongoing series of workshops designed to bring together people who are involved in Federal, regional, state, and local governmental and nongovernmental efforts to support nanotechnology-related economic development, in order to jointly address associated key issues. The workshop was one of a series of topical workshops sponsored by the NSET Subcommittee to inform long-range planning efforts for the NNI. This report is not a consensus document, but rather is intended to reflect the diverse views, expertise, and deliberations of the workshop participants.

Cover and book design

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Regional, State, and Local Initiatives in Nanotechnology

Report of the National Nanotechnology Initiative Workshop

May 1 - 2, 2012, Portland, OR

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Sponsored by the U.S. Government agencies participating in the
National Science and Technology Council
Committee on Technology
Subcommittee on Nanoscale Science, Engineering, and Technology
and by the
Oregon Nanoscience and Microtechnologies Institute

Additional partners include
FEI Company, City of Hillsboro, City of Gresham, Washington Economic Development Commission, Portland Development Commission, Business Oregon, Oregon State University, and the Center for Sustainable Materials Chemistry

Acknowledgements

Thanks are due to all of the workshop participants (see Appendix B), for taking the time to share their experiences and insights. Particular thanks are due to the sponsors of and additional partners in the workshop (see inside title page), to the writing team members (listed on p. 85), and to the members of the Workshop Steering Committee (listed below).

Workshop Steering Committee

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Special thanks are also due to David Mathews and Leah Wehmas for helping to facilitate and take notes at workshop breakout sessions, and to 2 Towns Ciderhouse, Portland, OR, for donating cider for the opening reception.

Preface

This report on Regional, State, and Local (RSL) Initiatives in Nanotechnology is the result of a workshop convened 1–2 May 2012 in Portland, Oregon, by the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council. The report was made possible with the help of the NSET Subcommittee's Nanomanufacturing, Industry Liaison, and Innovation (NILI) Working Group and with staff support from the National Nanotechnology Coordination Office (NNCO). The workshop is part of the NSET Subcommittee's long-range planning efforts for the National Nanotechnology Initiative (NNI), the multi-agency Federal nanotechnology program. The NNI is driven by long-term goals based on broad community input, in part received through workshops such as this one. The NNI seeks to accelerate the research, development, and deployment of nanotechnology to address national needs, enhance our nation's economy, and improve the quality of life in the United States and around the world through the coordination of activities and programs across the Federal Government. The NNI's reports are the result of an ongoing series of workshops organized by the NSET Subcommittee to inform the professional communities as well as the various agencies and organizations that have responsibilities for coordinating, implementing, and guiding the NNI.

The goal of the 2012 NNI Workshop on RSL Initiatives in Nanotechnology was to improve the outcomes of nanotechnology research, education, and business activities undertaken by U.S. organizations working to advance nanotechnology, such as small and large businesses, universities, research and education foundations, industry groups, and nongovernmental organizations. The strategy for reaching this goal is to exploit synergies between the various initiatives, promote sharing of information and resources, and develop ongoing mechanisms for relevant interactions. Specific objectives of the workshop are outlined in the Executive Summary and in Chapter 1.

On behalf of the NSET Subcommittee, we thank Skip Rung of ONAMI and Jim Kadtke of NNCO for taking the lead in organizing and in co-chairing the workshop. Thanks are also due to the NILI Working Group for leading the planning effort on behalf of the NSET Subcommittee, and to the members of the workshop organizing committee (listed on the facing page). We also thank all the speakers and participants for their time and efforts to join the workshop and to make their individual contributions to the workshop discussions and to this report. We offer special thanks to the workshop participants who stayed for the writing session following the workshop to help summarize the recommendations that arose from the workshop (see p. 85). This resulting report should be a valuable resource for the NNI and the nanotechnology RSLs as we work together to promote the commercialization of nanotechnology innovations for the benefit of the United States.

Lloyd Whitman	Altaf Carim	Robert Pohanka
Co-Chair	Co-Chair	Director
NSET Subcommittee	NSET Subcommittee	NNCO

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Executive Summary

The National Nanotechnology Initiative (NNI) Workshop on Regional, State, and Local (RSL) Initiatives in Nanotechnology was held 1–2 May 2012 in Portland, Oregon. This was the fourth in a series of RSL workshops sponsored by the NNI since 2003.[1] RSL organizations have vital roles in establishing the infrastructure, preparing the skilled workforce, and supporting the industries—especially startups and small and medium enterprises (SMEs)—that are critical to building an economically viable nanotechnology innovation ecosystem in the United States. Supporting partnerships with such organizations has been a goal of the NNI since its inception.

The 2012 NNI RSL workshop was attended by representatives of RSL initiatives, as well as by many representatives of businesses, various levels of government, and the member agencies of the NNI—in all, 103 participants, as listed in Appendix B. The workshop was dedicated to facilitating the sharing of relevant information and best practices among RSLs, and to continuing a dialog between RSL members and representatives of state and Federal NNI agencies concerning shared opportunities and mechanisms to advance commercialization of nanotechnology, to the benefit of all. The workshop, as detailed in the agenda in Appendix A, comprised two days of plenary meetings, small-session discussions, and expert presentations and panels. It was preceded by an outstanding series of tours of several Portland "Silicon Forest," nanotechnology-oriented businesses, startup support facilities, and advanced technology shared user facilities. It was followed on 3 May 2012 by a writing session to record the sense of the meeting and the recommendations of the participants.

This report of the workshop is not intended to be a consensus document but rather is intended to capture both the areas of consensus and the range of individual opinions expressed by participants. One theme rose to the top: The continuing global economic downturn after 2008 and the demise of many previously solid RSL initiatives since the third NNI RSL workshop in 2009 gave a strong sense of urgency to the participants' requests for more Federal attention to and matching financial support of the various regional, state, and local initiatives in nanotechnology.

Recommendations

Writing session members organized workshop recommendations into six categories: Commercialization, Collaboration, Policy, Workforce, Support for RSL Initiatives, and RSL Roadmapping. There are also a number of common themes and a "Next Steps" category to capture activities that can be begun immediately to keep interested parties in touch with one another.

[1] The earlier workshops were held in 2003, 2005, and 2009. The 2003 and 2009 workshops produced formal reports, available at http://nano.gov.

Common Themes

There were many comments from participants about the value of nanotechnology RSLs:

- The many fundamental science concepts and enabling tools and technologies underlying "nanotechnology" continue to comprise key elements of a durable advanced-technology-based economy in the United States.
- RSL initiatives in nanotechnology have a valuable role to play in establishing the foundation of that new economy due to their knowledge of and sensitivity to local needs and resources.
- NNI agencies' outreach to and support of RSLs are a critical component of the success of both RSLs and the NNI: all are committed to commercialization of new technologies, to economic development and job creation, and to advancing high-quality science, technology, engineering, and mathematics (STEM) programs in schools.

Regarding best practices, RSL and Federal participants identified needs for RSLs to:

- Focus on effective collaboration, multidisciplinarity, and clearly stated goals.
- Promote their success stories, especially of thriving spinoff companies, to state legislatures and potential investors.
- Similarly explain the unique role played by RSLs in nurturing the growth of SMEs *for the benefit of their individual regions* by means of commercialization expertise, workforce development, collaboration, advocacy, etc.
- Establish good working relationships with university technology transfer offices as well as with local industry and governments to promote RSL effectiveness.
- Find ways for RSL best practices to be shared and readily accessible.

Commercialization

RSL organizations. RSL leaders identified the need to focus their own organizations' support for nanotechnology-related startups on providing entrepreneurial advice and STEM education resources generally, and specifically, on providing assistance with intellectual property development, licensing agreements, access to user facilities at reasonable cost, and seed-stage funding.

Federal/state agencies. Workshop participants stressed the need for ongoing—although not necessarily extensive—support for RSLs. Not all such support needs to be direct funding. For example, Federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs might allow nonprofits such as RSLs to be eligible for inclusion in business support programs; Federal shared user facilities might find ways to reduce user costs for RSL members; and the Federal Government could lead activities to harmonize state and Federal regulations affecting nanotechnology businesses, partner in various ways with RSLs in promoting nanotechnology business growth and success, and communicate national and global innovation trends. One specific recommendation was to consider aligning goals and resources between the commercialization-focused NNI Signature Initiatives (http://nano.gov/signatureinitiatives) and the RSLs.

Collaboration

RSL organizations. Participants suggested that RSLs should implement the Institutes of Collaboration model for technology-based economic development as a means of defining their roles in their regions.[2] In support of regional collaboration among researchers, businesses, and stakeholders, RSLs should clearly define their goals and realistic metrics of success. Tools to forge collaboration should include workshops and conferences to define and address topics important to their communities, and social networking tools.

Federal/state agencies. Participants asked for increased incentives for universities and research institutions to provide shared user facilities and collaborative environments, especially by building requirements for multidisciplinary and multi-team collaboration into grant solicitations at the Federal and state levels, and by increasing "grand challenge"-type competitions for grants. A *disincentive* to collaboration has been the difficulties SMEs encounter when attempting to buy or license intellectual property (IP) from universities; sharing of new ideas and best practices is critically needed to improve this climate.

It was noted that nanotechnology-specific infrastructure and programs should not be developed in isolation from or in duplication of pre-existing publicly supported semiconductor, MEMS, etc., capabilities.

Policy

RSL organizations. To improve their chances of securing stable, long-term funding, RSLs must develop better arguments for why their programs should be considered for funding in comparison with other important state needs. In general, RSLs should develop strong, clear, and consistent messages about who they are and what they do, and take advantage of opportunities to communicate their ideas and viewpoints to the public and to the Federal and state governments. RSLs should take more active roles at the Federal, state, and local levels in the development of science standards for K–12 education in support of nanotechnology. They should also work at the state and possibly Federal levels to provide input on regulation, tax policy, and financial incentives for collaboration, angel financing, etc. The RSL community should also consider the formation of a nationwide alliance or council to help develop common goals, objectives, resources, and messaging in order to strengthen their voices within their individual states and at the national level.

Federal/state agencies. Federal programs such as the National Science Foundation I-Corps and Economic Development Administration i6 grants that promote innovation and commercialization should expand their scope to allow nonprofits such as RSLs to be eligible for participation or even for leading roles in their awards. The National Nanotechnology Infrastructure Network (NNIN) should be expanded and linked with other state and regional shared user facilities, such as the ONAMI User Facility Network and PA RapidNanoNet™, and give RSLs access to those facilities, which are critical to commercialization of nanotechnology. Federal and

[2] See p. 64 and forthcoming report from National Governors Association.

state regulatory agencies should make it a policy to reach out to RSLs to collaborate on collecting data to inform their policies related to nanotechnologies; to provide information to businesses and the public on the regulatory environment; and to promote environmental, health, and safety best practices for nanotechnology.

Workforce

RSL organizations. In the area of workforce development, the workshop participants focused on the importance of RSLs supporting strong STEM standards and curricula in K–16 education locally and being involved with community colleges to develop work-relevant, hands-on, mentored workforce training programs.

Federal/state agencies. State and local governments, the NNI, the Department of Labor, the Department of Education, and RSLs should collaborate to develop and deploy nanotechnology-focused STEM curricula to community and technical colleges to help educate and train the technical workers of the future. The programs should also link to resources such as NNIN and shared user facilities to provide hands-on experience. Business education and training and entrepreneurial skills should be incorporated into science curricula at the community college and university levels. The NNI should consider supporting the creation of an extensive, cohesive, certified repository of standardized nanotechnology educational content for educators nationally, and a more informal repository for the general public.

Support for RSL Initiatives

RSL organizations. As noted above, workshop participants argued that to better garner support for their work, RSLs need to do a better job of identifying themselves to political bodies and to the public, and develop clear goals and success indicators to foster confidence in their abilities to use financial and other support wisely and effectively. They should also take greater advantage of existing business, industry, and community resources that might provide business mentoring to entrepreneurs in the nanotechnology research community.

Federal/state agencies. Federal agencies should determine what mechanisms they have, or could implement, to make matching grants available to RSLs (e.g., 1:1) for gap funds for commercialization of nanotechnology-based products. Federal contributions of matching funds to RSL activities would not need to be extravagant (e.g., a very small percentage of current SBIR/STTR commitments) to make a dramatic impact on RSL effectiveness and longevity. NNCO should play a more effective role in distributing information to and about RSLs and about private and Federal programs relevant to RSLs via the “nano.gov” NNI website. Although beyond the scope of the RSL workshop, participants noted that national-level work is needed to create a more attractive high-tech investment environment in the United States (ideally, targeting U.S. investors and U.S.-based manufacturing especially).

RSL Roadmapping

RSL organizations. Workshop participants saw a clear need for a national roadmap for nanotechnology RSLs, in which RSLs all over the country provide input to identify common ground and shared goals, methods, and best practices, as well as accommodate regional differences and account for past weaknesses and failures. A national roadmap for nanotechnology RSLs should establish clear, shared goals and endpoints; define a plan to develop and disseminate best practices; define mechanisms to support nanotechnology-focused STEM educational resources; pinpoint the kinds of regional and state entities and resources that could be engaged; identify tools that could be used to inform and engage state and local governments and stakeholders; and define ways to leverage funding and resources from Federal and state governments and the private sector.

Federal/state agencies. Because it will help them to fully understand and develop broad mechanisms to support and collaborate with the various RSLs, Federal and state governments have a stake in the success of an RSL roadmapping exercise. They should be involved in the roadmapping undertaking and provide expertise and resources as available.

Next Steps

The workshop writing session participants noted four action items to be taken in the short to medium term to continue the dialogue among and about RSLs that developed at the workshop, and to help promote collaboration and information-sharing between RSLs and the NNI:

1. RSLs should take steps toward developing a virtual community of interest, for example, by organizing conference calls,[3] an email listserv, or social media to facilitate keeping engaged and developing future plans.
2. The NNI should consider having a small follow-on workshop with RSL leadership to discuss in concrete terms how to address workshop recommendations.[4]
3. RSLs should consider developing a dedicated website for their community,[5] possibly in collaboration with NNI/NNCO, to facilitate information gathering, outreach, networking, sharing of best practices and other information, virtual meetings, and development of "success stories."
4. NNCO should improve its online resources for RSLs on the NNI http://nano.gov website, including continuing to populate the new NNI Interactive Nanotechnology Resource Map[6] with additional information about the RSLs.

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[3] The first such conference call was held on 16 November 2012.
[4] This workshop was held on 27 September 2012.
[5] The National Nanomanufacturing Network has agreed to host such a website.
[6] http://nanodashboard.nano.gov/nanomaps/map.aspx.

CHAPTER 1

Introduction

Background and Purpose of the Workshop

The Workshop

The National Nanotechnology Initiative (NNI) has organized a series of four workshops on regional, state, and local (RSL) nanotechnology-based economic development initiatives since 2003.[7] The fourth in this series was held in Portland, Oregon, on 1-2 May 2012. The purpose of the workshop was to assess the current landscape of RSL nanotechnology initiatives and to help identify opportunities for leveraging of success strategies and resources among RSLs, and leveraging between the RSLs and related Federal Government activities and objectives. Principal themes of the workshop were: (a) the current landscape of U.S. RSL nanotechnology initiatives and their status; (b) current Federal resources available for RSLs; (c) RSL best practices, business models, and opportunities for partnering; and (d) the role of nanotechnology RSLs in future U.S. economic growth and job creation. Attendees and speakers included representatives from regional, state, and local organizations; the Federal Government; economic development groups; investors and entrepreneurs; technology leaders; and scientists and engineers from industry, business, government, academia, and the general public. The agenda for the workshop is included in Appendix A of this report. The workshop also included a poster session providing an opportunity for any regional, state, or local nanotechnology initiative or related organization to explain its activity. Presentations and other archived information from the workshop are available at http://nano.gov/node/732.

The Report

This report is organized into chapters based on the agenda shown in Appendix A. Chapter 1 is this introduction, including a brief summary of remarks by Sen. Ron Wyden at a reception the night before the formal opening of the workshop. Chapter 2 summarizes welcoming remarks on May 1 from Robert "Skip" Rung (ONAMI), Robert Pohanka (NNCO), Oregon Congresswoman Suzanne Bonamici, and Altaf Carim (Office of Science and Technology Policy, OSTP). Chapter 3 covers workshop Session A: Federal Resources & Initiatives for RSLs. Chapter 4 reviews Session B: Current Landscape of RSLs and their Status. Chapter 5 summarizes the results of the Day 1 breakout sessions on specific RSL issues. Chapter 6 includes the Day 2

[7] Two of these previous NNI RSL workshops resulted in formal NNI workshop reports; see http://nano.gov/publications-resources.

introductory presentations by Jim Kadtke (NNCO) and Oregon Senator Jeff Merkley. Chapter 7 covers workshop Session C: RSL Best Practices, Business Models, and Partnering Mechanisms. Chapter 8 summarizes Session D: RSLs and Future Economic Growth—From Concept to Action. Chapter 9 summarizes the results of a series of "Roadmapping Cafés" at which rotating groups of workshop participants addressed 12 separate topics. Chapter 10 provides a synthesis of workshop recommendations and possible next steps. Keynote presentations by Altaf Carim (OSTP), Ted Wheeler (Treasurer of the State of Oregon), Brian Markwalter (Consumer Electronics Association), Samuel G. Angelos (Hewlett-Packard), and Don Kania (FEI Company) are interspersed within the chapters, where they occurred in the agenda. Appendices include the workshop agenda, the list of participants, links to the poster presentations, and a list of acronyms used in the report.

Technology Tours

Before the formal beginning of the workshop, attendees enjoyed a full day of tours to a number of nanotechnology-related facilities in the Portland area, including Intel Corporation, FEI Company, and Portland State University's Business Accelerator and Electron Microscopy Center. In the evening, a welcome reception was held for all attendees, with comments by NNCO and ONAMI staff. Senator Ron Wyden, a long-time champion of nanotechnology, gave welcoming remarks and responded to questions from reception attendees.

Remarks by U.S. Senator Ron Wyden

Oregon's Senator Ron Wyden was a co-author of the 2003 21st Century Nanotechnology Research and Development Act (Public Law 108-153) and organizer of the Congressional Nanotechnology Caucus. He congratulated the U.S. nanotechnology community for its progress in research and commercialization, citing several example companies from the ONAMI gap fund, e.g., Home Dialysis Plus, Crystal Clear Technologies, Puralytics, and Pacific Light Technologies.

Senator Wyden recalled the early days of his interest in nanotechnology as a major opportunity for innovation-based economic development in the United States, when fewer local constituents were familiar with the topic but certainly were supportive of such opportunities. He mentioned the ongoing effort to reauthorize the 21st Century Nanotechnology R&D Act (Public Law 108-153) as well as the importance of continuing efforts in nanotechnology to enable creation of high-wage manufacturing jobs in the United States.

CHAPTER 2

Day 1 Welcoming Comments

Welcome by Robert "Skip" Rung

Robert D. "Skip" Rung, President of Oregon Nanoscience and Microtechnologies Institute (ONAMI), was the local host of the workshop and organizer of the pre-workshop tours on Monday, April 30. Mr. Rung welcomed workshop attendees to Portland, Oregon, the heart of the world-leading "Silicon Forest" high-technology region, known particularly for semiconductor R&D and advanced manufacturing, electron- and ion-beam nanotechnology tools, as well as for being an attractive work environment for young professionals.

Mr. Rung acknowledged returning participants from earlier RSL workshops held in Oklahoma City (2009), Chicago (2005), and Washington, D.C. (2003), and commended RSL leaders for their efforts in the increasingly important work of translating the large taxpayer research investment into commercialized innovations, economic impact, and high-wage jobs.

Welcome by Robert Pohanka

Robert Pohanka, Director of the National Nanotechnology Coordination Office (NNCO), began by noting the scientific and technical capabilities in Oregon, including those at Portland State University, the ONAMI incubation center, INTEL, and FEI. He emphasized that the goal of the workshop was to build on the past science and technology investments in nanotechnology and to focus on economic growth and job creation.

Dr. Pohanka expressed hope that the workshop would (1) evaluate the status of U.S. RSL initiatives in nanotechnology; (2) identify the Federal resources available to nanotechnology RSLs, RSL best practices and business models, and opportunities for partnering; and (3) identify the role nanotechnology RSLs could play in the future of U.S. economic growth and job creation. He recognized the previous NNI leaders participating in this workshop, including James Murday, Mihail Roco, Clayton Teague, and Travis Earles, as well as the other current NNI leaders in attendance, Altaf Carim (Assistant Director for Nanotechnology at OSTP) and Sally Tinkle (NNCO Deputy Director and NNI Coordinator for Environmental, Health, and Safety Research).

Figure 2.1. The new INTEL fabrication facility being built outside Portland.

Figure 2.2. Demonstration to the RSL tour group of an instrument inside an FEI facility.

Four examples of major scientific and technical advances that resulted from the NNI are: graphene for potential semiconductor applications, nanoscale-carbon-reinforced polymer composites for ultralightweight structural materials for airplanes and automobiles, nanoscale hybrid coatings for maintenance-free mechanical components, and nanostructured biological materials for potential targeted medical therapies.

The field of nanotechnology has been energized by NNI leadership, and as a result of their efforts, a new interdisciplinary culture of scientists and engineers is emerging with the capability to work across the fields of physics, chemistry, biology, electrical engineering, and others. These scientists and engineers will create the future technologies from the emerging nanotechnology building blocks.

Welcome by Congresswoman Suzanne Bonamici

Congresswoman Bonamici noted that she was Oregon's newest member of Congress, representing Oregon's 1st District, the technology-intensive Silicon Forest that includes Intel, FEI, and many other high-tech employers. She is a member of the

U.S. House of Representatives Committee on Science, Space, and Technology, and serves on both the Research and Science Education and the Technology and Innovation subcommittees.

Representative Bonamici welcomed RSL attendees to Portland and noted the critical importance of the high-technology industry to the Oregon 1st District. She also underscored the value of RSL initiatives such as ONAMI, citing several examples of nanotechnology-enabled startup companies in the Silicon Forest region that have benefited from such early-stage assistance, including Puralytics, Pacific Light Technologies, and other companies resident at the Portland State University Business Accelerator.

Keynote: Overview of the NNI and Related Federal Initiatives

Altaf Carim
Assistant Director for Nanotechnology, Office of Science and Technology Policy, Executive Office of the President

Dr. Altaf Carim set the stage for the workshop by explaining the structure and purpose of the National Nanotechnology Initiative (NNI), as well as some recent related initiatives being pursued by the current Administration. The NNI definition of nanotechnology is “the understanding and control of matter at dimensions approximately between 1 and 100 nanometers, where unique phenomena enable novel applications.” [8] *Nanotechnology* is shorthand for nanoscience, nanoengineering, and the technologies resulting from them. This definition has been consistent over all the Federal agencies involved in nanotechnology for almost a decade and serves as an organizing principle for their activities. Nanoscale phenomena have been identified as a highly important research area because materials exhibit new and sometimes unique properties at the nanoscale that are not observed at larger scales.

The NNI is the Federal initiative that encompasses the U.S. national investment in nanotechnology research and development. It is a high-level, broad, and inclusive initiative with activities ranging from fundamental research through development and commercialization, and across all technical areas. It is a Government initiative, representing a priority area for Federal investment and activity, but not a distinct funding program with separate budget authority. The membership and mission areas of the NNI are summarized in Figure 2.3.

[8] See the *NNI Supplement to the President’s 2013 Budget*, p. 3, for a detailed definition (http://www.nano.gov/node/748).

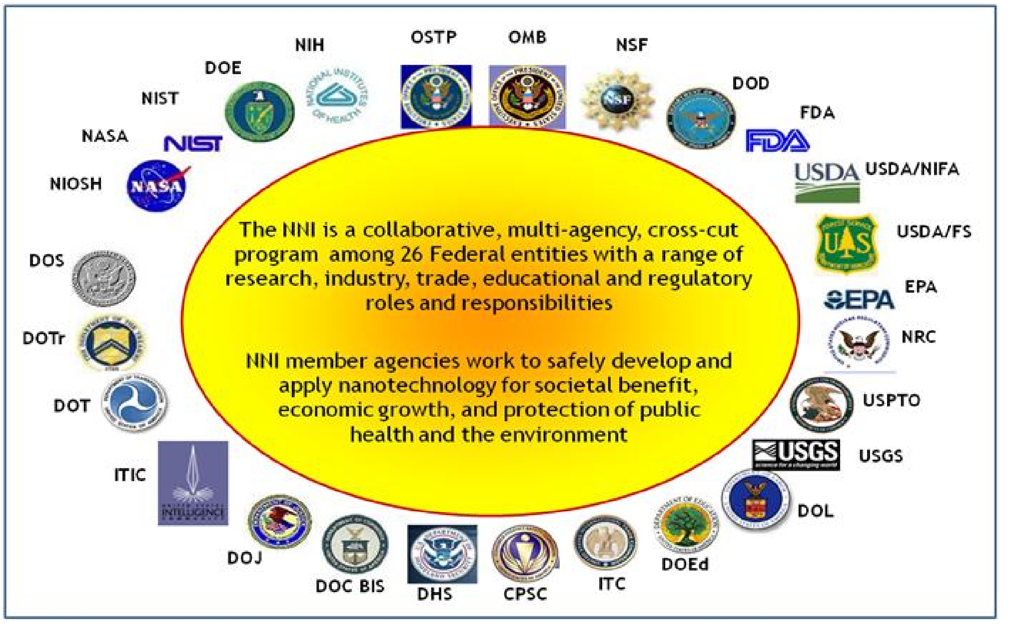

Figure 2.3. Membership and mission areas of the National Nanotechnology Initiative.

Several strategic planning and oversight documents (available on http://nano.gov) guide the NNI. These include the triennial NNI Strategic Plans (2004, 2007, and 2011), and the 2011 Environmental, Health, and Safety Research Strategy, as well as NNI supplements to the President's annual budget requests. These documents explain the administrative tools that the NNI uses to manage its investments, such as the Program Component Areas (PCAs), which track different categories of research activities and resources.

The history of the U.S. investments in the NNI, as well as the areas of investment, are summarized in Figure 2.4. The FY 2013 budget for the NNI will be about $1.8 billion across 15 agencies.

There are a number of specific initiatives under the NNI, such as the new Nanotechnology Signature Initiatives (NSIs), which are topical technology thrust areas expected to hold particular promise. At the time of the workshop there were three NSIs—on solar energy, sustainable manufacturing, and nanoelectronics; two more NSIs—on nanoinformatics and sensors—are now operational (see http://nano.gov/signatureinitiatives for details).

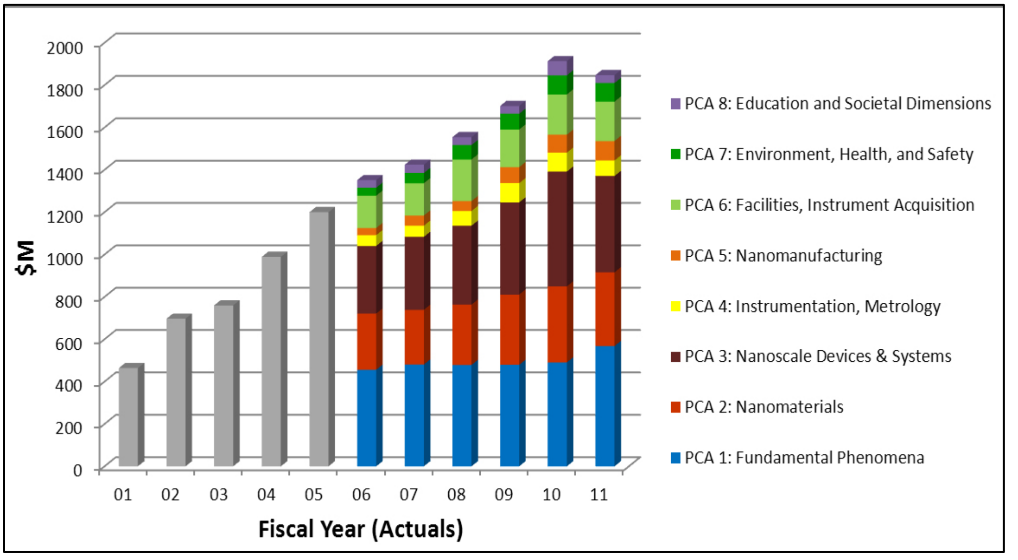

Figure 2.4. NNI Investments since 2001.

Regarding the administrative structure of the NNI, the highest level of management of science and technology within the Federal Government occurs within OSTP, headed by the President's Science Advisor, and contained within the Executive Office of the President (EOP). To aid in its duties, the OSTP uses and manages two entities: the National Science and Technology Council (NSTC), consisting of Cabinet-level representatives from agencies that fund R&D, and the President's Council of Advisors on Science and Technology (PCAST), consisting of advisors external to the Federal Government. The direct Federal management of the NNI is coordinated by the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the Committee on Technology (CoT) of the NSTC. NSET currently has four topical working groups: Global Issues in Nanotechnology (GIN); Nanotechnology Environmental and Health Implications (NEHI); Nanomanufacturing, Industry Liaison, and Innovation (NILI); and Nanotechnology Public Engagement and Communications (NPEC). NNCO provides technical and administrative support to the NSET Subcommittee, serves as a central point of contact for Federal nanotechnology R&D activities, and provides public outreach on behalf of the NNI. Figure 2.5 summarizes the structure of the management of the NNI.

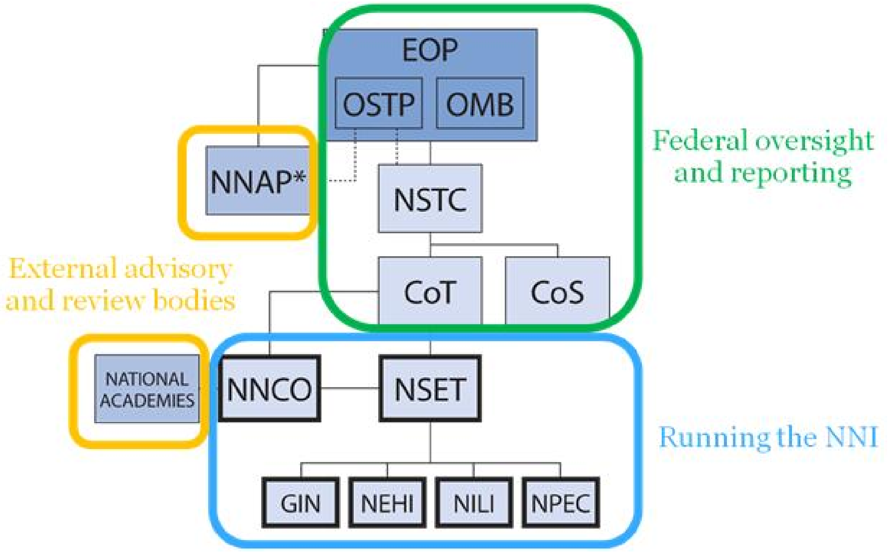

Figure 2.5. Management of the National Nanotechnology Initiative.

Other major research initiatives within the U.S. Government that relate to the NNI include two long-standing research initiatives: the Global Climate Change Research Program (since 1989), and the Networking and Information Technology Research Program (since 1991). Two new initiatives begun in 2011 are the Materials Genome Initiative (MGI), intended to accelerate the development of advanced materials, and the Advanced Manufacturing Partnership (AMP), which will support a large-scale collaboration between government, academia, and industry to "invest in the emerging technologies that will create high quality manufacturing jobs and enhance our global competitiveness." [9] The Administration requested $2.2 billion for Advanced Manufacturing in the FY 2013 budget, including $1 billion for a National Network for Manufacturing Innovation (see http://www.manufacturing.gov for details). Both of these initiatives have connections to and synergies with the research being funded by the NNI. "Startup America," a White House-led initiative, started in 2011 to coordinate with the private sector to accelerate high-growth entrepreneurship across the country. Startup America should be of particular interest to RSLs and state organizations that are interested in technology-based job creation; more information is on the Startup America website http://www.s.co.

Additional information on nanotechnology and the NNI is available on the NNI website, http://nano.gov.

[9] http://www.whitehouse.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership

CHAPTER 3

Session A: Federal Resources & Initiatives for RSLs

Plenary A-1: Retrospective on NNI RSL Initiatives

Clayton Teague

Consultant and Former Director of the National Nanotechnology Coordination Office

Clayton Teague presented a retrospective of past NNI RSL workshops and provided recommendations on future steps for these initiatives.

Mike Roco of the National Science Foundation (NSF) and other early NNI leaders convened two regional nanotechnology workshops—one at UCLA[10] and one at Rice University[11]—before the first of the three formal NNI RSL workshops. The reports of the 2003 and 2009 NNI RSL workshops (available on http://nano.gov) contain many good ideas and some interesting perspectives on the evolution of RSLs over the past 10 years. Figure 3.1 shows known RSL initiatives in 2003, and Figure 3.2 shows known RSL initiatives in 2012.

The RSLs shown for 2012 are those found active after examining available websites, talking with NNCO staff, Vince Caprio (Executive Director of the NanoBusiness Commercialization Association), and others. Only four of the initiatives of those active in 2003 were still active in 2012. Others have either ceased or diminished their activities, evolved into new ones now shown, or ceased due to lack of funding or other less obvious reasons. None of the multistate initiatives active in 2003 are now active.

Some of the early and enduring pioneers of nanotechnology commercialization and RSL initiatives include the Oklahoma Nanotechnology Initiative (ONI), the Oregon Nanoscience and Microtechnologies Institute (ONAMI), North Carolina's Center of Innovation for Nanobiotechnology (COIN), the Nanotechnology Institute (Pennsylvania), the National Nanomanufacturing Network, and the NanoBusiness Commercialization Association (previously the NanoBusiness Alliance).

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[10] http://www.nsf.gov/crssprgm/nano/activities/finalreport_ucla.jsp

[11] http://www.nist.gov/tpo/publications/upload/nanotech_workshop.pdf

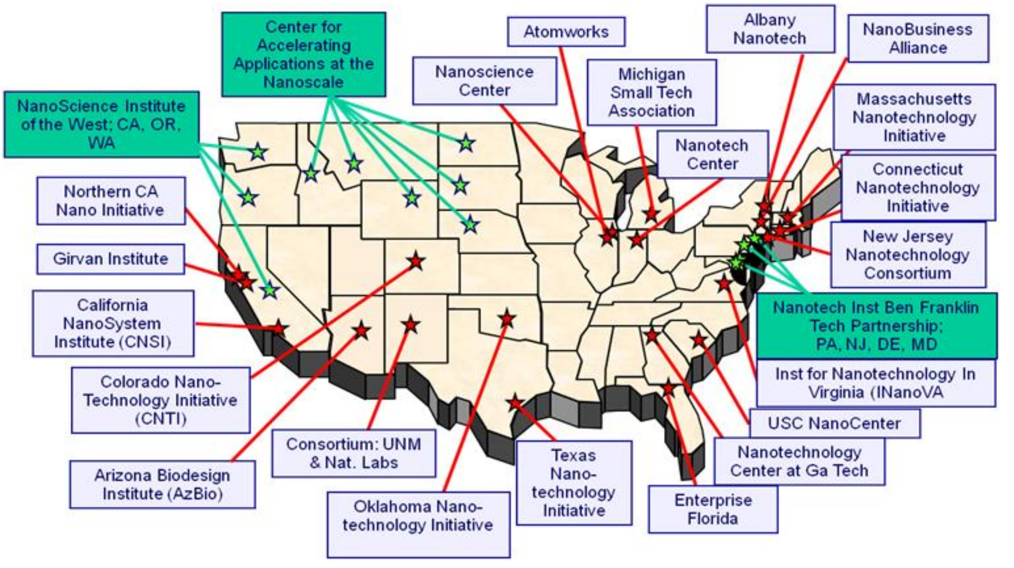

Figure 3.1. Sampling of RSLs in 2003 (multi-state initiatives highlighted in green).

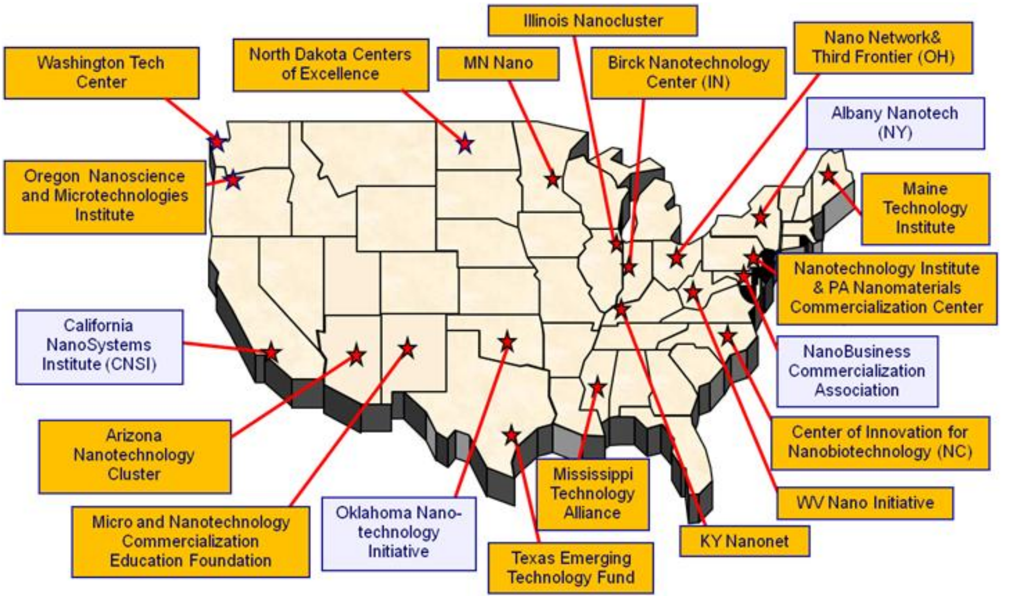

Figure 3.2. Sampling of RSLs in 2012 (four persisting since 2003 highlighted in purple).

Earlier RSL workshops:

- Offered opportunity for dialogue among RSLs, Federal, state, and local governments, academia, and industry.
- Explored mechanisms to better link the NNI and RSLs.
- Explored and summarized various models for these initiatives.
- Examined various sources of funding and resources for initiatives.
- Shared lessons learned and best practices.
- Identified common goals and objectives among the initiatives.

With this background, the community should consider the formation of a nationwide alliance of RSLs in order to develop common goals, objectives, and messaging, in order to strengthen their voices within their individual states and at the national level. In the formation of this alliance, inputs should be solicited from representatives from all existing RSLs and from corresponding state governments, industry, and relevant Federal agencies. Such an alliance should first develop a plan of action that includes objectives for each goal that are "SMART" (*s*pecific, *m*easurable, *a*cceptable to all participants, *r*ealistic, and with a clearly agreed upon *t*imeframe for accomplishment).

Plenary A-2: Nanomanufacturing and the NNI Signature Initiative

J. Alexander Liddle

National Institute of Standards and Technology

Dr. Liddle, Group Leader of the Nanofabrication Research Group at the National Institute of Standards and Technology (NIST), gave an overview of the evolving area of nanomanufacturing and the Federal initiatives and programs that are now developing to promote this area. Manufacturing is a large and important sector of the U.S. economy, providing high-paying jobs and generating the most additional economic activity per dollar spent of any economic sector. Manufacturing makes a disproportionately large contribution to U.S. innovation, accounting for 70% of private sector R&D. However, key indicators suggest that U.S. manufacturing has lost ground to the global competition; for example, the U.S. trade balance for advanced technology products plummeted over the past decade to an $81 billion deficit in 2010.

A renaissance in U.S. manufacturing is a top Administration priority; a number of recent reports highlight this need. The Advanced Manufacturing National Program Office (AMNPO; http://manufacturing.gov/amnpo.html), hosted by NIST, is one effort that is supporting this priority, by creating an interagency whole-of-government approach to Federal activities in advanced manufacturing. In the United States a gap exists between R&D activities and the deployment of technological innovations in the domestic production of goods. To bridge this gap, the President proposed in his FY 2013 budget a new National Network for Manufacturing Innovation (NNMI), a network of institutes to bring together local stakeholders—including companies large and small, local and state governments, universities and community colleges, and Federal Government agencies—to tackle industrially relevant advanced manufacturing challenges.

A decade of investment in the National Nanotechnology Initiative has led to a large number of breakthroughs in materials and devices. The challenge now is to translate those breakthroughs into commercial products (see Figure 3.3).

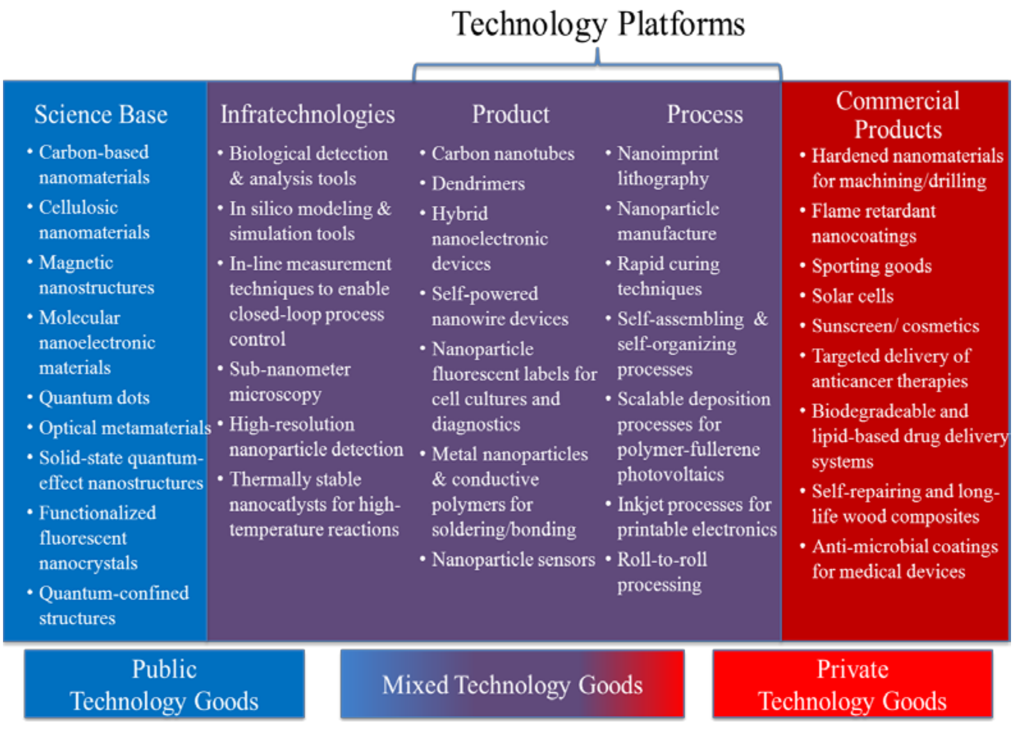

Figure 3.3. *Bridging the gap between basic science and manufacturing*: Like other complex technologies, nanotechnology spans a range from purely public (basic research) to purely private (commercial products) investments, but there are many opportunities for shared investments in technology platforms and infratechnologies, which provide benefit to both the public good as well as to private firms. *(Figure courtesy of Greg Tassey of NIST)*

The Nanotechnology Signature Initiative (NSI) on Sustainable Nanomanufacturing seeks to do just that, with its two thrust areas focused on:

- *Materials*: nanocellulosic, nanocarbon-based, and optical metamaterials.
- *Manufacturing technology*: roll-to-roll processing and online metrology tools.

Research is directed towards finding economically and environmentally sustainable ways of producing these new materials in ways that can be scaled up to meet the demands of emerging application areas and maintain U.S. leadership in nanomanufacturing.

As an example, carbon nanostructures can be produced in large quantities using continuous processes, but new *nanoscale measurement techniques* are needed to provide the insights necessary to tune the growth processes to produce the desired nanostructures under the optimum conditions. In addition, *novel techniques that are sensitive to nanoscale structure, but that can operate at high throughputs*, are needed for inline process control.

As part of the NSI, NIST has a program to advance the state of the art in detailed measurement of the growth of carbon nanostructures and their behavior in nanocomposite materials. These measurements will be used to enable the development of sophisticated models that link the properties of the nanocomposites to the type and distribution of carbon nanostructures they contain.

These models will also be used to determine the microwave response of the nanocomposite materials as a function of carbon nanostructure type and distribution, ultimately enabling the development of microwave measurements that are sensitive to the nanostructure but that can be used in a high-throughput manufacturing setting for online, closed-loop process control.

Panel Session A: Federal Resources for RSL Initiatives

This first panel session of the workshop was intended to provide an overview of the resources that several NNI-member Federal agencies had available that could possibly benefit RSL nanotechnology initiatives. Sally Tinkle, NNCO Deputy Director, moderated the panel; representatives of six Federal agencies gave brief overviews of their organizations' activities related to nanotechnology.

Panel Overview
Sally Tinkle
National Nanotechnology Coordination Office

Dr. Tinkle thanked the panelists for contributing their time and expertise to the meeting, stressing that cooperation between the Federal Government and state and regional initiatives is an important priority, and that this panel would set the stage by providing information about Federal nanotechnology-related activities.

Panel Presentation 1
Sandra Chapman
National Cancer Institute, National Institutes of Health (NIH)

NIH has a strong interest in nanotechnology and currently funds about $400 million per year in nanotechnology R&D. This R&D is spread across several institutes and is coordinated by several mechanisms, including the NNI; the NIH Nanomedicine Roadmap; the NIH Nanotechnology Task Force; as well as various centers such as the National Cancer Institute (NCI); the National Heart, Lung and Blood Institute (NHLBI); the National Institute of Biomedical Engineering and Bioengineering (NIBIB); the National Institute of General Medical Sciences (NIGMS); the National Institute of Environmental Health and Safety (NIEHS); and the National Human Genome Research Institute (NHGRI). Each center has specific areas of nanotechnology interest in terms of tools/instruments and applications. The disease-focused centers (e.g., NCI and NHLBI) are looking for new drugs, therapies, and diagnostics; the technology-based centers (e.g., NIBIB and NHGRI) are looking for technology development and tools; and NIGMS and NIEHS are interested in tools and basic discovery about nanomaterials.

There is an ongoing program announcement at NIH for R&D related to nanoscience and nanotechnology, and an ongoing study section. Examples of technologies that are funded include microfluidics, nanocantilevers, nanobiomimetic structures, and nanomaterials in general. The NCI Alliance for Nanotechnology in Cancer is a large coordinated effort that includes multiple networks such as the Centers for Cancer

Nanotechnology Excellence, Cancer Nanotechnology Platform Partnerships, and the Nanotechnology Characterization Laboratory. This overall effort had an initial Phase I (2005–2010) focused on basic research, and it is now in Phase II (2010–2015), focused on commercialization. The research initiatives of the program have been very successful, having produced over 1300 journal articles, and involving over 80 companies, 34 of which were formed within the last 4 years. Also, as of 2012, the alliance has coordinated the creation of a public-private partnership called Translation of Nanotechnology in Cancer Research (TONIC), which has attracted participation by many large and small companies in a wide range of research areas.

Panel Presentation 2
Chris Cannizzaro

U.S. Department of State (Office of Space and Advanced Technology, Bureau of Oceans and International Environmental and Scientific Affairs; NSET Subcommittee agency representative, and Chair of the NSET Subcommittee's Global Issues in Nanotechnology Working Group)

Chris Cannizzaro described the Department of State's (DOS) first Quadrennial Diplomacy and Development Review (QDDR), inspired by the Department of Defense (DOD) Quadrennial Defense Review. This review recommended some organizational changes within DOS. For example, the DOS manages over 300 embassies and diplomatic missions all over the world and is the global face for the U.S. Government; the QDDR recommended that ambassadors be viewed as "CEOs" within their countries to empower them to coordinate U.S. Federal and private sector activities in those countries, which would include scientific and business activities.

Much of the scientific and technical expertise in the DOS resides within the Bureau of Oceans and International Environmental and Scientific Affairs. The Space and Advanced Technology office has emerging technologies under its purview; nanotechnology is a high-priority issue area in terms of diplomatic efforts. These efforts include advancing U.S. technical leadership, advancing U.S. economic and national security interests, and promoting fair trade and market-based competition globally.

There are a number of mechanisms for domestic and international coordination of nanotechnology research and commercialization activities. One main element is the Global Issues in Nanotechnology (GIN) working group of the NSET Subcommittee. GIN takes the lead on international activities of the NNI, such as representation at international meetings, standards negotiations, and treaty negotiations. Two other primary coordinating mechanisms are the Working Party on Nanotechnology (WPN), primarily focused on policy, and the Working Party on Manufactured Nanomaterials (WPMN), focused on environmental and human health issues, both under the Organisation for Economic Co-operation and Development (OECD). In March 2012, the NNI and OECD hosted a joint workshop on the economic impacts of nanotechnology; the report from that workshop is under development. There are also several bilateral commissions, such as the U.S.-EU and the U.S.-Russia commissions, which both have strong nanotechnology themes, and a number of multilateral efforts, such as the Strategic Approach to International Chemicals Management negotiations under the United Nations Environment Programme (UNEP). Another major activity is international standards development for nanotechnology, the focus of which has been the International Standards Organization (ISO) Technical Committee on Nanotechnologies (ISO TC/229).

Panel Presentation 3
Khershed Cooper

U.S. Department of Defense (Office of Naval Research; Co-Chair of the NSET Subcommittee's Nanomanufacturing, Industry Liaison, and Innovation Working Group)

Khershed Cooper gave an overview of nanotechnology activities within the Department of Defense. DOD is vast and has a variety of activities in nanotechnology in all the armed services. DOD research organizations that fund significant nanotechnology programs include the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Defense Threat Reduction Agency (DTRA). These activities are coordinated across DOD by the Office of the Secretary of Defense (OSD). Each of these offices has representatives on the NSET Subcommittee. The central theme of DOD nanotechnology research is to develop and transition results from basic research to help the warfighter.

DOD is one of the founding agencies of the NNI and has participated actively over the years, in both joint and collaborative R&D activities as well as in NSET Subcommittee roles. DOD currently participates in the GIN, NILI, and NPEC working groups, and it is currently involved in two Nanotechnology Signature Initiatives, *Sustainable Nanomanufacturing* and *Nanoelectronics for 2020 and Beyond*.

As of 2012, DOD funds roughly 50% basic and 50% applied projects in nanotechnology. These projects are divided among a variety of program areas within different DOD offices, many of which are shown in Tables 3.1 and 3.2 below. These include the "foundational" research programs such as the Core and MURI program (at Technical Readiness Level [TRL] 1), Applied Research Programs (TRL 2-3), Advanced Technology Development programs (TRL 4-6), Component and Prototype Development (TRL 7-8), and Transition /Maturation programs (TRL 9). DOD also has manufacturing-oriented programs, such as its SBIR/STTR programs, its Defense Manufacturing Technology (ManTech) programs, and programs under the Defense Production Act Title III.

The DOD nanotechnology research budget at a high level is summarized in Table 3.1. An important DOD R&D focus area currently is in nanomanufacturing, including research funded through DOD Multidisciplinary University Research Initiative (MURI) programs. Some of the technology focus areas for DOD nanotechnology research are summarized in Table 3.2.

Table 3.1. DOD Technology Focus Areas (dollars in thousands)[12]

CROSSCUT	FY2010	FY 2011	FY 2012
DoD			
National nanotechnology initiative	439,700	418,600	368,000
Fundamental nanoscale phenomena and processes	138,000	180,500	162,900
Nanomaterials	59,000	33,100	24,100
Nanoscale devices and systems	168,600	146,400	132,300
Instrumentation research, metrology, and standards	6,700	2,400	2,100
Nano-manufacturing	26,400	27,700	20,200
Major research facilities and instrumentation acquisition	35,600	25,700	16,400
Environment, Health and Safety	0	0	0
Education and Societal Dimensions	5,400	2,800	10,000

Table 3.2. DOD Nanotechnology Research: Application Areas and Examples

DOD Applications	Examples
Electronics and Sensing	IR focal plane arrays
Power and Energy	Fuel-cell catalysts
Structural Materials	"Fuzzy" carbon fibers
Coatings	Photoactive, self-cleaning films
Multifunctional Devices	Spin-polarized active devices
Materials & Systems Prognosis	Quantum-dot thermography
Energetics	Nano Al and reactive materials
Chem/Bio Defense	Chemical sensors

DOD views the interagency collaborative nature of the NNI as very useful, and workshops such as this one can help extend those efforts further into the regional and private sector communities. The annual Nanotechnology for Defense Conference (NT4D; see http://www.usasymposium.com/nano/) is an excellent source of information on current DOD nanotechnology research activities.

Panel Presentation 4
Ben Schrag

National Science Foundation (Program Director, SBIR/STTR)

Ben Schrag described some of NSF's funding for nanotechnology under its SBIR/STTR programs, which are aimed almost exclusively at small businesses, whereas most of NSF's other programs primarily fund universities. NSF funds mostly basic research. Its FY 2012 budget was almost $7 billion; almost all of this money is allocated as external grants and contracts. In addition to basic research, NSF has a STEM (science, technology, engineering, and math) education focus, and increasingly, an innovation focus.

Nanotechnology-related research expenditures at NSF are summarized in Figure 3.4.

[12] See http://nanodashboard.nano.gov for updated budget information.

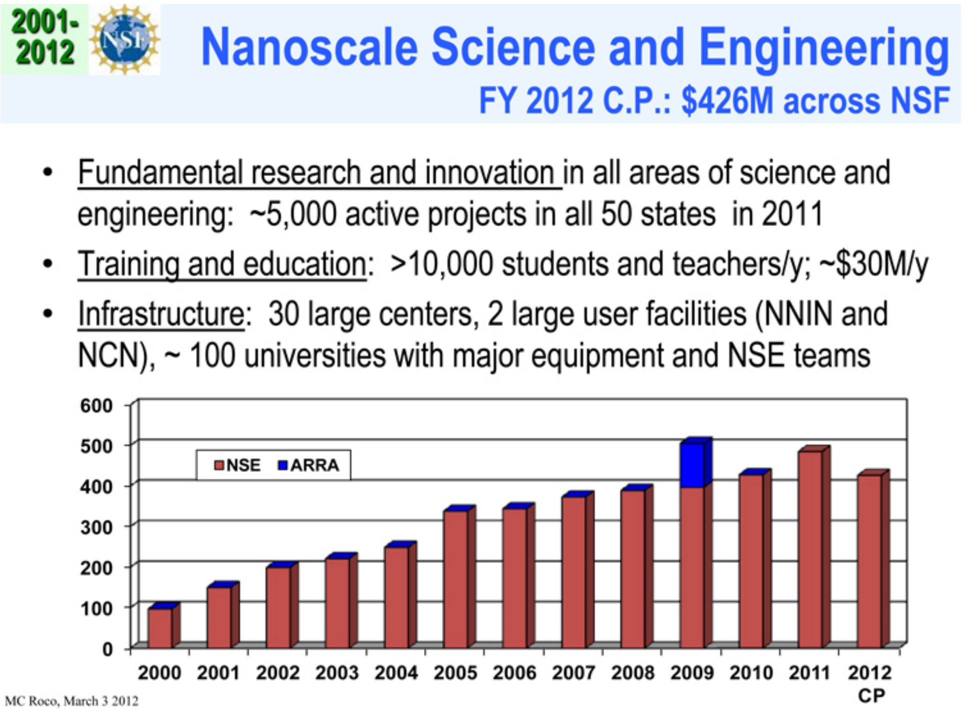

Figure 3.4. Nanoscale science and engineering expenditures at NSF, 2001–2012 (courtesy M. Roco 2012).

NSF tends to award research grants to individual project areas based on decisions by program managers who are subject matter experts; there is no one large-scale programmatic focus area on nanotechnology. The numbers quoted in the above graphic are therefore aggregates across a wide range of smaller program areas. Some insight into how funding is awarded thematically by the NSF can be obtained by looking at the organizational chart of the different directorates within NSF, which in turn are subdivided into divisions (see http://www.nsf.gov/). The Division of Industrial Innovation and Partnerships deals mostly with for-profit businesses and is probably the most commercially focused part of NSF.

Program areas and resources within NSF that are directly related to nanotechnology are as follows:

- National Nanotechnology Infrastructure Network: http://www.nnin.org/.
- Centers: Nanoscale Science and Engineering Centers (NSECs), National Nanotechnology Infrastructure Network (NNIN), Network for Computational Nanotechnology (NCN), etc.: http://www.nsf.gov/crssprgm/nano/info/centers.jsp.
- Program Solicitations (e.g., Scalable Nanomanufacturing): http://www.nsf.gov/pubs/2012/nsf12544/nsf12544.htm.
- Small Business Programs (SBIR/STTR): http://www.nsf.gov/eng/iip/sbir/.
- Industry/University Cooperative Research Centers Program (I/UCRC): http://www.nsf.gov/eng/iip/iucrc/.

The last two areas are specifically focused on commercialization activities, as is the new Innovation Corps (http://www.nsf.gov/i-corps), which began operations within the last year.

Panel Presentation 5
Altaf Carim

Assistant Director for Nanotechnology
Office of Science and Technology Policy
Executive Office of the President
[on detail from the Department of Energy]

Dr. Carim began his talk by saying that the Department of Energy (DOE) was unable to send a current representative of its nanotechnology R&D programs to the RSL workshop, but since he had spent 11 years there in this area at DOE, he would be able to cover the topic. DOE resources available for nanotechnology researchers include the Nanoscale Science Research Centers (NSRC) user facilities; various other DOE laboratory user facilities such as light sources and electron microscopes; funding for basic research from the DOE Office of Science; as well as other programs with some relevance, such as ARPA-E and the Energy Frontier Research Centers.

The NSRCs are very valuable because they offer a full range of equipment, technical expertise, synthesis and fabrication capabilities, characterization, and modeling for nanotechnology applications. There are five NSRCs, located at the Brookhaven, Argonne, Oak Ridge, Lawrence Berkeley, and Los Alamos/Sandia national labs, each focusing on different application areas.[13] These NSRCs have a distinct operations approach: each has its own internal staff research program but also serves outside users throughout the scientific community. They are available to all researchers, regardless of affiliation, nationality, or source of research support; they are available at no cost for nonproprietary work, and proprietary work is also possible on a cost-recovery basis, with users retaining their intellectual property. The access is based on peer merit review of submitted proposals by external panels. The instruments are operated primarily by facility staff, with a large majority of time made available to general users via reviewed proposals. Collaboration with facility scientists is an important potential benefit to users but is not required. These user facilities could be a very valuable resource for nanotechnologists in academia and the business community.

Panel Presentation 6
David Porter

U.S. Economic Development Administration, Portland Office, Seattle Region

David Porter briefly discussed how to get funding from the U.S. Economic Development Administration (EDA) and what it is generally used for. EDA's mission is to lead the country's economic development capacity-building efforts. EDA organizes these efforts through six main regions covering the United States. EDA has

[13] http://science.energy.gov/bes/suf/user-facilities/nanoscale-science-research-centers/

traditionally provided grants for physical infrastructure (sewer, water, rail, etc.) but in recent years has had an increasing emphasis on programmatic funding for technology. Examples of the latter include the building for a technology incubator or a piece of equipment for a laboratory. Entities eligible for grants include public institutions such as municipalities, educational institutions, or certain types of nonprofit institutions. Most grants require 50% matching funding from another source, because EDA places a great deal of value on collaboration for funded projects. EDA currently has six major investment priorities (see http://www.eda.gov). EDA prefers outcomes that lead to the retention or creation of permanent higher-skill, higher-wage employment opportunities that have a positive economic development effect on a community.

Keynote: The Imagination Economy: The Public Sector can be a Partner and a Potent Catalyst to Building a Stronger Economic Future

Ted Wheeler
Treasurer of the State of Oregon

Ted Wheeler, Treasurer of the State of Oregon and a proponent of technology-based economic growth, spoke about the importance of supporting innovation and emerging technologies.

Mr. Wheeler conveyed greetings from Oregon Governor John Kitzhaber, M.D., who would have liked to have been present at the RSL workshop but could not, due to a prior commitment. Both the Governor and he share a deep commitment to innovation because it reflects Oregon's pioneering past, its present as a small-business-intensive state, and its aspirations for future prosperity and improvement in average incomes. This commitment is manifest in strong support for the Oregon Innovation Council (Oregon InC).

Oregon InC's investments include the Signature Research Centers, which help Oregon compete nationally by making available to businesses the research power of 450 affiliated scientists and 11 laboratories focused in key areas such as nanoscience, microscale technologies, green building and renewable energy technologies, and bioscience. These centers have helped create over 26 new businesses, and have helped them tap over $115 million in private investment. One of those new businesses is Home Dialysis Plus (HD+), which received research and funding help from ONAMI. HD+ has invented a revolutionary portable kidney dialysis machine about the size of a piece of roll-on luggage. HD+ has since been backed with $50 million in capital from Warburg Pincus.

The 2012 Oregon Investment Act was conceived with the help of business leaders looking at capital gaps. A study commissioned by Oregon's Office of the Treasurer and the Oregon Community Foundation, in partnership with Business Oregon, verified that there is a capital gap facing most of our industry sectors, and particularly startups. The Act will consolidate and coordinate economic development resources from all state agencies and steer them to where they are needed to make success more likely. Regarding nanotechnology, the study found that there is a stark need for next-stage (i.e., B-round and above) capital resources for companies commercializing Federal research (i.e., most university spinouts) and related workforce development.[14]

[14] http://www.oregoncf.org/Templates/media/files/jobs_and_economy/oregon_capital_scan.pdf

CHAPTER 4

Session B: Current Landscape of RSLs and their Status

Plenary B-1: Overview of the Current RSL Landscape

Jim Mason

Oklahoma Nanotechnology Initiative

Jim Mason, Executive Director of the Oklahoma Nanotechnology Initiative and co-chair of the 2009 NNI RSL Workshop, began his talk by saying that it was a great time to be a regional, state, or local (RSL) nanotechnology initiative. In the first decade of nanotechnology initiatives much was accomplished, and more resources are now available to nanotechnology researchers and companies than ever before. Nanotechnology research leads us to great discoveries nearly every day, and the knowledge of nanotechnology grows by leaps and bounds and knows no geographical boundaries.

RSLs are defined by the communities that support them, and no two are exactly alike. Some RSLs have survived "the Great Recession," and many have faded away. Those initiatives that have survived did so through local and/or state funding and support. Even those initiatives that faded away left many nanotechnology-based companies still viable. Many of the RSLs morphed into something different than what they were in the beginning.

Nanotechnology research infrastructure resources abound, and many are directly accessible by researchers and companies. An extensive research infrastructure created by the National Nanotechnology Initiative now includes over 80 research centers and networks supported by the National Science Foundation. There are also five research facilities at the DOE National Laboratories—Sandia/Los Alamos, Brookhaven, Argonne, Lawrence Berkeley, and Oak Ridge—that are making extensive research opportunities available to nanotechnology researchers in every state.

More resources are available at the Nanotechnology Characterization Laboratory of the National Institutes of Health and at the National Institute of Standards and Technology Center for Nanoscale Science and Technology. There are many Department of Defense laboratories. Fifteen Federal agencies have budgets for nanotechnology research; others have related regulatory responsibilities or programmatic interests. In 2011 the NNI provided $73.2 million in funding for research on instrumentation, metrology, and standards and $185.8 million for major research facilities and acquisition of new instrumentation.[15] In 2012, Congress reauthorized the Small Business Innovative Research (SBIR) program.

These are good times for the nanotechnology researchers and the nanotechnology companies the RSLs represent, but there is an issue regarding resources for the RSLs themselves. In 2006 and again in 2009, the "ask" was stated time and again by the RSLs, "Help us, help our companies and our country by providing some form of funding support for the RSLs." In 2009, an answer seemed to surface suggesting that, while it is difficult for the Federal Government to fund individual state and local nanotechnology initiatives, it might be possible to provide funding for multistate or regional initiatives. Within a few months of that workshop, a number of states began to work toward forming regional nanotechnology initiatives. Oklahoma, New Mexico, Colorado, Texas, and Arizona formed the SouthWest Nano Consortium; Pennsylvania, New Jersey, and Delaware formed the Mid-Atlantic Nanotechnology Alliance; Oregon and Washington State established cooperative efforts between them. The Alliance for Nanohealth: Partnering for Medicine formed, among others. But after numerous meetings, conferences, and collaborations were initiated by RSLs, no Federal funding for RSLs ever materialized, and many of the regional initiatives withered on the vine.

The NanoBusiness Alliance, now the National NanoBusiness Commercialization Association (NanoBCA), focuses on nanotechnology issues on a national scale and now gives nanotechnology companies and RSLs a voice in Washington.

RSLs across the United States have tried various business models.[16] Four models emerged initially; only three of those remain:[17]

1. The State Government Investment Model.
   Examples:
   a. The Oregon Nanoscience and Microtechnologies Institute (ONAMI).
   b. University at Albany College of Nanoscale Science & Engineering: $50 million in seed money generated $3 billion in private investment.
   c. Ohio / Nortech and Nano-Network of Ohio. Ohio voters extended a billion dollar commitment to 2016.
   d. North Dakota Department of Commerce sets up Centers of Excellence.
   e. Pennsylvania – PA NanoMaterials Commercialization Center provides grants for companies to commercialize nanotechnology-enabled products.
   f. Texas – Texas Emerging Technology Fund.
2. The Government Organization Model.
   Examples:

[15] NNI Supplement to the President's FY '13 Budget, Table 3, p. 9 (http://nano.gov/node/748).
[16] For more information, see Chapter 2 of the report from the 2009 NNI Workshop on Regional, State, and Local Initiatives in Nanotechnology (http://www.nano.gov/node/589).
[17] Updated information on current RSLs, including links to their websites, is available at http://www.nano.gov/initiatives/commercial/state-local.

   a. Oklahoma Nanotechnology Initiative – $1.5 to $2 million annually for nanotechnology commercialization; includes the Nano Education Initiative, Nano camps.
   b. South Dakota – actively recruiting nanotechnology companies.
3. The Single-Goal Model.
   Example:
   a. Nanotechnology Foundation of Texas: it achieved its goal and shut down.
4. The Volunteer and Business Association Model.
   Examples:
   a. Arizona Nano Cluster – all funded by local nanotechnology companies, no state funds.
   b. Colorado – initially funded by local nanotechnology companies but no longer operational as an initiative.

There are some other RSL-like entities, for example:

- The North Carolina Center of Innovation for Nanobiotechology (COIN).[18]
- Kentucky's efforts to pursue EPSCOR (Experimental Program to Stimulate Competitive Research) funding for nanotechnology research.
- New Mexico has two Federal labs involved in nanotechnology but no formal state initiative.
- West Virginia has had the WV Nanotechnology Institute, which is morphing to include more than nanotechnology (under the name TechConnectWV).
- Hawaii is now seeking to help nanotechnology companies and researchers.

The number-one need of RSLs is *funding*, but they also need to communicate better with each other and the public; get together more often (not just every 3 years or when they are manning a booth at a trade show); collaborate more at the RSL, company, and researcher levels; and improve technology transfer from Federal labs and universities.

The RSL landscape is growing and morphing, and it is important to realize how far we have come in "all things nano" in one decade. It is not too late for any state to get involved in nanotechnology. The body of nanotechnology research is growing exponentially. The equipment used to operate at the nanoscale is getting better and better. Companies are utilizing nanotechnology to make new, improved, and often disruptive commercial products. Jobs are being created across the nation. Most importantly, this is still just the beginning!

[18] The North Carolina Department of Commerce's Office of Science & Technology has also been promoting nanotechnology in that state (see http://www.nccommerce.com/scitech/nanotechnology).

Plenary B-2: National Overview of RSLs and Technology-Based Economic Development

Mark Skinner

Vice President, State Science and Technology Institute

Mr. Skinner began by saying that although he is an ally and practitioner of technology-based economic development (TBED), he would give a frank overview of what he thought were ongoing problems in that community, as well as in public support for science and related issues. He also played devil's advocate in asking some hard and pointed questions of the audience. He condensed the themes of his talk into three phrases: *humility*, *relevance*, and *impact maximization*.

The State Science and Technology Institute (SSTI; http://www.ssti.org/), was originally created in 1996 starting from 36 state science advisors from around the country who wanted to share best practices about their investments in science and technology, commercialization, and innovation. Carnegie Corporation of New York provided the original funding, and SSTI is currently a national organization headquartered in Columbus, OH, with a membership that includes more than 200 organizations from regional, state, local, and academic institutions. SSTI is funded through a range of mechanisms but principally by the Federal Government, with a large portion coming from the Manufacturing Extension Partnership (MEP) program at NIST. SSTI manages a website, http://www.regionalinnovation.org, which focuses on best practices in regional economic development through TBED and innovation. Some nanotechnology RSLs are referred to on that site. SSTI also puts out a free weekly electronic digest that covers many of the issues this workshop is focused on.

The *humility* aspect of this talk concerns itself with the austere state budgets that can be expected for the foreseeable future. This means that it will be a real challenge for organizations promoting TBED, such as nanotechnology RSLs, to maintain funding as other issues crowd them out in state budgets. It will no longer be sufficient for TBED organizations to talk about the potential for economic development from technology, but they will actually have to show results. Therefore, TBED organizations will have to develop much better arguments for why their expenditures should be on the table with other important state needs, such as health care benefits.

In the majority of states, the legislatures are practically at war with their universities. For example, most major universities have significantly increased tuition over the last few years to cover shortfalls, angering both citizens and state legislators alike. The legislatures have often, in turn, cut state support of universities, which causes the universities to increase tuition further. Some legislatures are now looking at implementing criteria for universities to justify further increases. University-affiliated TBED organizations will have to operate in this hostile climate for the foreseeable future when they seek public funding for projects.

Many state policies and programs are created specifically to entice or solicit funding from Federal programs. Because of the significantly different ways that Federal agencies operate and fund projects, and the large number of states and state programs, this creates a very complicated environment that is not optimally suited to yield positive outcomes. For example, it is often very difficult for regional initiatives comprised of several states to satisfy requirements from multiagency TBED programs, such as EDA's "i6" grant program, because the constituent agencies may have different or even conflicting regulations and metrics for performing on the grant. States and municipalities are typically only incentivized to invest in projects that produce economic returns within their own geographic areas, and so multistate regional initiatives are very hard to promote or get funded. It may be that our financial incentive systems must be changed to encourage regional TBED initiatives.

There are 4 basic kinds of economic development: (1) community development, (2) workforce development, (3) infrastructure development, and (4) since the 1980s, technology-based economic development. Increasingly today, technology is becoming a facilitator of all kinds of economic development, and so the first three of the list above are now becoming a subset of TBED. Hence, nanotechnology RSLs should understand that they need to incorporate aspects supporting all these kinds of development using their technology development objectives, so that at a minimum they do not appear elitist. The kinds of jobs that RSLs and other TBED activities are aimed at creating may not be accessible to a significant fraction of Americans because of their income or education level. So how do we make the outcomes that we aim to create more *relevant* and appealing to the average citizen?

Another aspect is the global economic reality. For example, the middle class of India is now bigger than the entire population of the United States and growing rapidly. They will be buying an increasing number of goods and services in the future. So RSLs should be thinking about global markets and in turn about global partnerships to access those markets. This means RSLs need in-house expertise and activities aimed at exporting.

Regarding *impact*, when seeking funding for TBED projects, an RSL needs to talk about the jobs to be created, the average wages to be paid, the private funding it will attract, and the business revenue (that will result in tax revenues). This will create a more entrepreneurial mind-set, more of an operational business mind-set, and will be more effective in communicating value to the state and Federal program managers evaluating project proposals.

Panel Session B: RSL Representatives Discuss Their Challenges and Successes

This second panel session of the workshop was intended to provide a perspective on the challenges and issues currently facing nanotechnology RSLs. Six representatives of RSL and RSL-related organizations gave presentations about their organizations. The panel was moderated by Vince Caprio, Executive Director of the NanoBusiness

Commercialization Association, a trade organization that has supported the U.S. nanotechnology business community for over a decade. These presentations were followed by a question and answer period to round out the one-hour session. Summaries of the individual presentations follow.

Panel Overview
Vince Caprio
Executive Director, NanoBusiness Commercialization Association

Vince Caprio began by saying that the number of speakers and limited time meant that they would each try to give only a top-level overview of many important issues facing RSLs. He has been in the nanotechnology world for over 12 years, and his experience has been that recent economic events were a "perfect storm": there has been a convergence of three large-scale economic and financial factors that have affected the RSLs specifically. The first of these is the two recessions the United States has experienced in the last ten years, including the Great Recession starting in 2008, which we may still be in. The second is that although there was a lot of investment in nanotechnology by venture capital (VC) firms in 1999–2001, after the "dot-com" bubble burst, 40% of these were gone by 2002, and very little financial gain has come out of the nanotechnology investments, even ten years later. The direct effect of this on the nanotechnology community was that by 2008, VC investment in nanotechnology "went off a cliff". The third factor was the lack of liquidity that exists for VCs in nanotechnology firms, such that over ten years, there have been only a handful of initial public offerings (IPOs) by nanotechnology companies, and only a handful of mergers/acquisitions, so again, there has been very little real return on nanotechnology investments by large venture capital firms.

According to the National Venture Capital Association, over the 10-year period from 2001 to 2011, the average return on VC has been only 0.9%, versus 3.3% for the Nasdaq and 2.8% for the S&P. Historically, the 25-year average for these numbers has been an average return on VC of 21%, versus 8% for the Nasdaq and 9% for the S&P 500, so the risk/return world has been turned upside down. These numbers are for emerging technology investments in general; for nanotechnology, the 10-year average returns since 2000 may actually be negative. One result of this has been that, nationally, VC investment has gone from a peak of $105 billion in 2000, with 649 active funds, to $18.2 billion last year, with the number of funds down to 169. And the trend is still downward.

There were only five successful nanotechnology company exits in 2011, and very few in previous years, so the outlook is not good for financial returns on nanotechnology investments in the foreseeable future. Increased numbers of exits would mean better rates of return on VC investments, more subsequent investment, more business creation and growth, more jobs being created, and ultimately more funding and investment in nanotechnology RSLs. But the future is uncertain at present.

Panel Presentation 1
Jim Mason
Executive Director, Oklahoma Nanotechnology Initiative

The seed of the Oklahoma Nanotechnology Initiative (ONI) organization was planted by an NSF EPSCOR grant in 2000 that allowed for the purchase of nanotechnology equipment and the hiring of research staff and graduate fellows. This facilitated the creation in 2003 of the ONI by three nanotechnology companies and several private individuals. This led to an appropriation by the Oklahoma legislature in 2004 of $125,000 for each of two years, and in 2005 Jim Mason was hired as Executive Director. In 2006, the Oklahoma governor signed the Nanotechnology Sharing Incentive Act, which provided $2 million per year. The goal of this program was to create world-class nanotechnology companies in Oklahoma; the number of such companies increased from 6 in 2006 to almost 70 in 2012. A few of these companies are pure nanotechnology companies, such as SouthWest NanoTechnologies (SWeNT); however, many more are using nanotechnology in some form to improve products in other application areas.

In 2010 ONI-funded projects raised about $10 for every dollar of state investment, and in 2011 this was more like $18 for every dollar of state investment. Additionally, over 250 high-wage jobs have been created since the ONI inception, and each of the 29 projects funded has resulted in a new or improved commercial product going to market.

Another interesting aspect of ONI is that its awards do not necessarily need a university connection to get funded; quite a few have been to stand-alone companies. This has helped in seeding clusters of companies that are beginning to use nanotechnology. Such companies are now scattered throughout the state of Oklahoma, and the process is continuing to grow.

Panel Presentation 2
Griff Kundahl
Executive Director, Center of Innovation for Nanobiotechnology

Griffith Kundahl shared perspectives from his experience as an executive team member of four different RSLs over the course of ten years. He was a founder and General Counsel of the NanoBusiness Commercialization Association, a founding member of the Southwest Nanotechnology Consortium, and Executive Chairman of the Colorado Nanotechnology Alliance. He now serves as Executive Director of the Center of Innovation for Nanobiotechnology (COIN). Two of those initiatives continue to be active, and two others have not survived, so he has insight on what might and might not work for nanotechnology RSLs.

The current state of nanotechnology RSLs could be summarized by the phrase, “adapt or die.” For example the NanoBusiness Alliance started an initiative around 2001 to create local nanobusiness “hubs,” among them the Colorado Nanotechnology Initiative, to seed nanotechnology RSLs. There were originally two different nanotechnology RSLs in Colorado; however, both died from lack of funding. But with help from EDA and the Colorado legislature, the remnants reformed in 2006 into the Colorado Nanotechnology Alliance, which managed to engage with a wide variety of partners and was very active for four years until funding again ran out. There is still a large nanotechnology research and business community in Colorado, but the coordinated effort that could be provided by an RSL does not exist. COIN in North Carolina constantly strategizes about how to be adaptive as an organization so as not to repeat some of the mistakes seen in previous RSLs.

In summary, the number-one challenge for nanotechnology RSLs is funding. RSL organizations across the country have provided a wide range of essential services for over a decade ranging from high-level resource assessments, to public awareness and education, to targeted networking. Unfortunately, the vast majority of these organizations have disappeared due to a lack of reliable funding. However, much of the value of their efforts stills exists in the communities they have built, their assessments and reports, and other work products. Surviving RSLs and defunct RSLs alike can be reinvigorated and mobilized with coordinated planning and new funding models that take into account the challenges of supporting the type of fundamental work they provide in what is still a nascent sector of the commercial economy.

Panel Presentation 3
Robert "Skip" Rung

President and Executive Director, Oregon Nanoscience and Microtechnologies Institute

The Oregon Nanoscience and Microtechnologies Institute has been the beneficiary of many good friends, such as the State of Oregon appropriating $47 million in capital and operating funds, and Hewlett-Packard (HP) donating an entire building for ONAMI's use. Much of ONAMI's success can likely be attributed to its strong planning efforts, including setting well-conceived goals and metrics for success. Goals include growing the nanotechnology research enterprise in Oregon; providing access to high-tech research facilities, particularly for startup companies; and facilitating and enabling high-tech startups to raise capital to grow. Since ONAMI began operations in 2004, the nanotechnology research enterprise in Oregon has grown about fourfold, up to about $35 million statewide. A recent major success has been a $21.5 million investment from NSF for the Center for Sustainable Materials Chemistry.

Another ONAMI initiative, its "High-Tech Extension" concept,[19] is based on the idea that nanoscience facilities and equipment can best benefit technology development when they are conveniently located and easy to use by businesses. The number of clients using such open nanotechnology shared user facilities (typically located at Oregon universities) has grown by three times since the inception of the program.

[19] http://www.onami.us/nano-network/industry-users

Most importantly, ONAMI has created a Gap Fund program and commercialization model[20] to help researchers and businesses get technologies across the "valley of death" based on building teams of researchers and entrepreneurs and providing critical gap funds to get the company started (see Table 4.1 and Figure 4.1) and positioned for its first commercial funding.

Table 4.1. ONAMI Model for Investment Sourcing

Technology Stage	Company Stage	Funding Source
Research Result	(NA)	NNI Grants
Proven Prototype	Formation	Gap Grants (state + Federal)
Products, Sales	Development	Early Stage Investors
Product Line Expansion	Growth	Various (private)

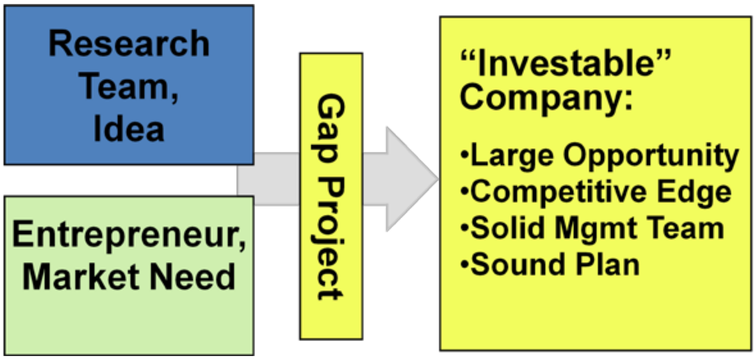

Figure 4.1. ONAMI model for investment sourcing.

ONAMI has helped invest $103 million in leveraged funding as of May 2012, including in such companies as Puralytics and Pacific Light Technologies, two examples from its growing "Green Nano" startup portfolio.[21]

ONAMI has the right model, but a future challenge will be to continue to succeed in the coming era of tighter Federal and state budgets. Corporate budgets are getting tighter as well, and in particular, limited availability of venture capital for manufacturing-oriented startups is an increasing problem. A final and related problem is when startups create or advance intellectual property (IP) based on local research efforts, but then choose, or are effectively forced for financial reasons, to have the product manufactured elsewhere (particularly offshore), so that states or localities that have assisted in the very early stages wind up not reaping the full economic benefits of their investments.

[20] http://www.onami.us/commercialization/
[21] http://www.onami.us/index.php/green_nano

Panel Presentation 4
Kevin Conley
Nanotechnology Education Program Coordinator, Forsyth Tech

Kevin Conley discussed how he teaches nanotechnology skills at Forsyth Tech, a 2-year community college in Winston-Salem, NC. Programs for teaching nanotechnology at Forsyth Tech have been funded at a level of $750,000, principally by grants from Wachovia and Wells Fargo banks. Forsyth Tech teaches students practical knowledge about nanotechnology and commercial applications, in anticipation of nanotechnology acting as a broad “economic force multiplier,” much the way the oil and electronics industries have been in decades past.

North Carolina’s nanotechnology community has three main focus areas: nanoelectronics, nanomaterials, and nanobiotechnology. Application areas in the state include textiles, vehicles, and renewable energy. Additional biotechnology applications focus on drug delivery, pharmaceuticals, and regenerative medicine.

Whereas other countries are funding nanotechnology centers of excellence with large government funding, American RSLs in nanotechnology are reliant on revenue from the sale of nanotechnology-enabled consumer products. There are three challenges for the nanotechnology community: the rise of international competition; the importance of environmental, health, and safety (EHS) issues; and how STEM and workforce education in the United States need to be aligned with the needs of industry.

Panel Presentation 5
Osama Awadelkarim
Associate Director of the Center for Nanotechnology Applications and Career Knowledge (NACK), Pennsylvania State University

NACK is part of the Center for Nanotechnology Education and Utilization (CNEU) of Pennsylvania State University (Penn State). Penn State has some experience in human infrastructure development for the nanotechnology workforce. The Penn State Center for Nanotechnology Applications and Career Knowledge has four main mission areas. The first is to build partnerships in nanotechnology education among research universities, 2-year community and technical colleges, and 4-year colleges and universities—principally through sharing of resources (courses, laboratory facilities, staff)—and to use these partnerships to create job-relevant degrees in nanotechnology. This model was developed at Penn State about 12 years ago through funding from the State of Pennsylvania and was aimed at increasing Pennsylvania’s technical workforce. In 2001, NSF began funding this activity and created the NACK as a regional center; in 2008 NSF promoted it to be the national center on career nanotechnology education, with a mission to promote this model across the United States.

This resource-sharing model facilitates the other three missions of NACK, namely to enable a broad nanotechnology education in synthesis, fabrication, characterization, and applications at 2-year community and technical colleges; to educate students for careers in a spectrum of industries by advocating a knowledge base that can be used in many types of applications and companies; and to ensure that this broad nanotechnology education is one that students can build upon throughout their professional careers.

In order to accomplish these missions, NACK has developed a number of significant resources, such as a suite of six nanotechnology course modules for universities and community colleges, a teaching cleanroom for hands-on experience, and Web-based environments for remote-access control of sophisticated nanotechnology equipment. NACK has also helped several other states implement this model in their educational infrastructure and has educated staff and teachers nationally. To date, NACK has trained almost one thousand educators from thirty states in nanotechnology education. It runs live monthly webinars using its educational materials, has developed a portal to the NACK resources (http://www.nano4me.org), and runs Nanotech Academies, high school curriculum enhancement programs, and supplies downloadable modules.

One of the key aspects of NACK is that it works very closely with industry; for example, it has a National Industry Advisory Board with members from such major companies as Alcatel-Lucent, Boeing, Corning, DuPont, General Electric, Johnson & Johnson, Lockheed Martin, and 3M. This board helps the NACK to continuously revise and improve its educational modules to reflect advancing technology and changing industry needs. This process has allowed preparation of students for a very wide range of nanotechnology positions and careers in different industrial sectors. In the most recent PCAST review of the NNI, the NACK was highlighted as one nanotechnology STEM program that has proven very successful.

Panel Presentation 6
Ed Cupoli
Chief Economist, SEMATECH

Ed Cupoli originally worked at the College of Nanoscale Science and Engineering (CNSE) at the State University of New York (SUNY)-Albany, but is now the Chief Economist for SEMATECH, a consortium of 87 companies in the electronics industry. In the 1980s SEMATECH was set up as a public‑private partnership to promote U.S. research in the electronics industry in response to challenges by Japan. Figure 4.2 shows a simple way to conceptualize the value added and success recipe of SEMATECH.

SEMATECH has been a very successful public‑private partnership and has helped keep the U.S. electronics industry, the second most R&D-intensive sector in the United States, in the lead globally.

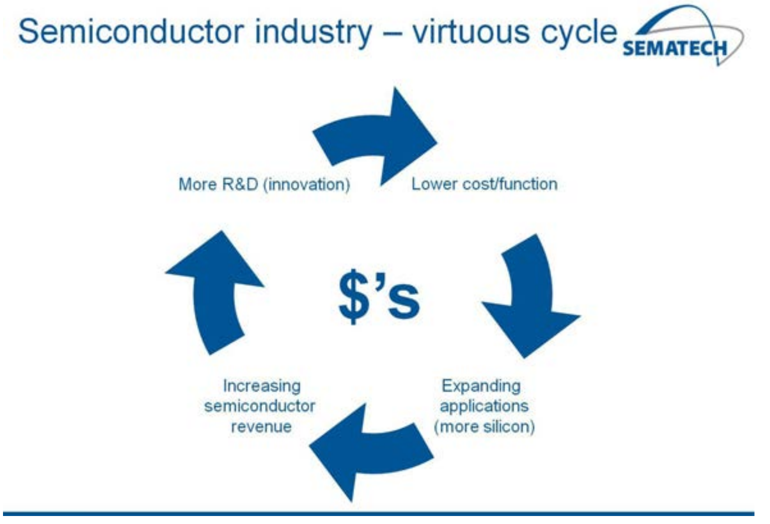

Figure 4.2. SEMATECH's concept for maximizing R&D value added.

In the mid-1990s, the New York state legislature awarded about $5 million to start a nanotechnology laboratory at SUNY-Albany, and then around 2001, funded CNSE with about $50 million, with a matching grant of $100 million from IBM. CNSE has become one of the leaders in nanotechnology-related research focused on electronics, and it has continued to attract large funding rounds. Recently, another large partnership was announced that will have total funding of over $4.5 billion, involving the State of New York, Federal agencies, and a large number of companies.

RSL best practices and policy could be better informed if a number of case studies were developed. Specifically, such case studies should analyze specific RSLs in considerable detail, including operational models and actual numbers for financial activities and metrics for economic impact. This could take much of the "fuzziness" out of understanding how RSLs evolve and help in developing better models and practices.

CHAPTER 5

Day 1 Breakout Sessions: Specific Issues

Session 1. Resourcing the Commercialization Lifecycle

Co-Chairs: Skip Rung, Ben Schrag
Notetaker: Leah Wehmas

Background

The scientific promise of nanotechnology has not delivered tangible commercial benefits as quickly or as broadly as once predicted. Part of the reason for this relates to the formidable structural challenges facing businesses attempting to bring research results to the market place, especially in nanotechnology. In recent years, with the consolidation of the venture capital industry and the recent economic downturn, these challenges have grown. RSLs themselves have also faced intense funding pressure from cuts in state and local budgets, with many downsizing or disappearing entirely.

This open breakout session brought together academic researchers, industrial scientists and engineers, entrepreneurs, government officials (Federal, state, and local), and other stakeholders. The focus of the discussion was on funding and other challenges, to both RSLs themselves, and to the variety of small and/or early-stage businesses attempting to translate nanotechnology research into products and services in the commercial marketplace.

Summary of Questions/Answers

Three questions were posed to the session participants, who shared their unique experiences and views.

1. What are the major ways RSLs are being funded, and what are the major challenges in each of these areas?

There are three main categories of funding sources, in rapidly descending order of importance, for true RSLs (i.e., public–private partnerships with a central economic development component, as opposed to purely research/academic institutes):

- **State funding**. This can take the form of a state-funded university center, a state agency program staffed with state employees, or a competitive grant/contract to a private entity (most likely a 501(c)(3) nonprofit corporation). RSLs of this type almost always fall under the umbrella of the state economic/business development department and are expected by legislators to result in high-wage job creation and clear financial payback. Virtually all surviving/continuing RSLs in the United States are of this type.

Challenges:

- The RSL vision and mission, together with convincing results and metrics, must be sold to new leadership on an annual or biennial basis.
- Legislators have diverse/local interests and many pressing requests of an urgent nature; their time frame of interest for results is much shorter than the time frame required for research results to yield jobs.

- **Industry consortium/trade association funding**. This category is narrower in scope than "all of nanotechnology" and is crafted to satisfy clear business needs (related to talent, common IP interests, shared infrastructure, etc.) of an industry cluster or concentration. RSLs in this category do not typically have state or regional economic development or job creation as an objective, and are more likely to be adjuncts or components of Federal centers (such as an NSF ERC or I/UCRC) than stand-alone efforts.
  Challenges:
  - These efforts are usually tied to secondary/non-core business objectives and subject to cancellation.
  - Industry turbulence results in frequent changes in leadership and/or championship, which needs to exist both at the detailed technical and decision-making managerial levels.
  - It is very difficult to sustain member interest over a period of years and to collect renewal payments.
  - Industry does not see economic development as its job, and in any case is increasingly globally (rather than regionally) focused.
- **Philanthropic/foundation funding**. RSLs in this category can take the form of institutes inside universities or stand-alone efforts and can have varied purposes, including medical breakthroughs (e.g., Knight Cancer Center at Oregon Health & Science University), scientific research (e.g., Kavli Institutes), and student development (including entrepreneurship). It is rare for these to have regional economic development as an objective except to the extent that is a downstream benefit of research and talent development.
  Challenges:
  - It is challenging to package RSL-type activities into a convincing sales pitch for charitable foundations.
  - Most foundations have very limited funds for this kind of activity and extremely limited funds for economic development.

2. In terms of RSLs assisting startups and small businesses, where are the major resource gaps, for example, in translational research funding, early/later stage capital, or accessible infrastructure?

The participants in the discussion offered a wide range of areas in which RSLs might play a role in assisting startups and other small businesses. Many of these issues relate to common gaps seen in technology-driven small businesses. The panel discussion focused on a set of issues where RSLs generally possess the competency and resources to assist. Among the key issues discussed were the following:

- **Early-stage IP**. Very early-stage companies often lack funding and/or expertise in understanding how and whether to file for patent protection. Many entrepreneurs see patent applications as an early prerequisite, but do not understand the patent process or properly gauge the cost, especially when international filing is required. RSLs could play a role by either providing small amounts of funding or by connecting these small businesses with local experts (e.g., patent attorneys).
- **Licensing technologies out of universities**. New startups attempting to license technology out of universities often negotiate at a disadvantage due to an asymmetry of information. These transactions can take months or even years and often result in terms that make it difficult or impossible for the small business to attract follow-on support. RSLs could bring local networks to bear by providing advisors or honest brokers to assist new startups in this process.
- **Equipment and facilities**. Many technology-based small businesses rely on universities or other shared facilities for access to expensive capital equipment. RSLs can play a role by identifying local and state resources and advising small businesses on what options are available.
- **Seed-stage funding**. Funding at the very early stages of the small business lifecycle has always been challenging, and traditional “seed-stage” funding avenues have become even more inadequate in recent years. RSLs can play a role in providing funding on the order of $10,000 to $250,000, to allow new businesses to work on their proof-of-concept or work up a business case. This funding can be provided through a formal “batch” process like a competition, or informally through private discussions.
- **General entrepreneurial advice**. Perhaps most importantly, many technology small businesses are launched by new entrepreneurs who lack business training and/or a network of advisors. RSLs can prove invaluable in their ability to connect these businesses to serial entrepreneurs, business professionals, or domain experts who can informally mentor the company principals. These local connections can also then indirectly support later stages of company development (fundraising, recruiting a CEO or Board of Directors, etc.).

3. What viable options are available for RSLs that lose their public funding?

The short and realistic answer is that there is really no alternative for funding the original RSL mission if it has lost state support. The best advice is probably to refocus and restart with a fresh mission. If the state remains committed to the more general principle of innovation-based economic development, a new initiative updated to current conditions may receive support. RSLs can also attempt to focus their resources on providing some technology solutions or services to industry, to try to generate an ongoing revenue stream, but this can be difficult. Attracting foreign investment is another option, but this is even more difficult.

Session 2. Fostering the U.S. Nanotechnology Workforce

Co-Chairs: Jim Murday, Kevin Conley
Notetaker: Dave Matthews

Background

There is widespread recognition that Federal, state, local, and private investment is needed in the emerging technologies that will create economic growth and high-quality jobs, and therefore enhance the global competitiveness of the United States. A critical component of that commitment is science, technology, engineering, and math (STEM) education. An educated workforce and an informed public are essential for achieving the goals of national as well as of regional, state, and local (RSL) nanotechnology initiatives, and for fulfilling the promise of nanotechnology to benefit society. The pull–push relationship between industry and education is critical in the development of the future workforce to support U.S. economic growth. Especially for K–12 and community/technical colleges, it is important that substantive communication occur between educational institutions, government, and industry. RSLs have the potential to serve as a focus for this interaction.

Nanoscale science and engineering (NSE) education is critical for several reasons. To produce an informed citizenry, capable of making benefit–risk evaluations, NSE must be embedded in the education of the general population, both through formal K–12 education and in informal education (e.g., science museums and educational television). A skilled workforce for manufacturing of "nano-enabled" products will require additional technical training at community and technical colleges. Entrepreneurs, business persons, systems engineers, etc., who will be implementing commercial applications of nanotechnology must have bachelor's- and master's-degree education that familiarizes them with NSE concepts. Finally, the discovery of new NSE properties and materials that enable innovation requires master's- and PhD-level education and research that must be at least multidisciplinary, if not transdisciplinary. An assessment of NSE education status and opportunities has recently been published.[22]

Even though the nanoscale is acknowledged as essential to emerging technologies, there is the problem of negative public perception. In the initial years of the NNI, while it was new and compelling, the news coverage reported both the benefits and risks associated with exploiting the nanoscale; this was followed by a period where more of the press coverage dwelled on the risks. Care must be taken to avoid public backlash, as occurred for genetically modified foods.

[22] "Developing the Human and Physical Infrastructure for Nanoscale Science and Engineering," J. Murday, M. Hersam, R. Chang, S. Fonash, and L. Bell, in *Nanotechnology Research Directions for Societal Needs in 2020*, M.C. Roco, C.A. Mirkin, and M.C. Hersam, eds., Springer, ISBN 978-94-007-1167-9 (2011).

Summary of Questions/Answers

1. Do nanotechnology RSLs and affiliated business partners have difficulty finding personnel that are trained in nanotechnology? At what level?

The initial response from the breakout session group to this question was yes, it is generally difficult to find trained nanotechnology personnel, but it also depends on the definition of nanotechnology, and the research or business sector involved. For example, many companies involved in "nano" don't self-report as such, and it might be wise to reach out to these for further advice and engagement. Another general problem is that it is often assumed that nanotechnology R&D requires a PhD, but that is usually not true for a wide variety of job descriptions. A majority of positions probably only require a technical degree, but trained people even at this level are scarce. Some participants said that 2-year technical degrees and even many 4-year degrees may not be worth much, because there is not enough exposure to actual equipment or facilities.

There was no clear consensus among the group on what a nanotechnology training curriculum should consist of. A discussion arose about how nanotechnology training curricula should be developed. Many expressed the view that input from industry about personnel needs is vital, and that there should be industry advisory groups to help develop general training curricula as well as industry sector-specific curricula. Another topic was the current lack of high-quality curricula and tools for teaching nanotechnology. The point was raised that course accreditation tends to drive out bad programs, but does not necessarily ensure good programs. It was also noted that industry needs more nanotechnology training tools that are "tools of understanding", for example to teach statistical analysis, process control, and experimental design.

2. Commonly, employers recognize a need to employ three technicians for every PhD in their companies. What benefits and barriers do you see in this strategy?

The participants generally agreed that the ratio of technicians to PhDs can be fairly high, at least 3 to 1, and perhaps even 5 to 1, but some commented that many companies cannot find enough trained technicians for even a 2-to-1 ratio. Overall, a high ratio of technicians to PhDs saves money because technicians are usually much cheaper, and that ratio increases with the size of the company. There was a discussion about using ongoing nanotechnology coursework and training tools to augment the skills of people with 2-year and 4-year degrees, as one potentially cost-effective strategy.

3. What nanotechnology STEM or workforce training resources are available for RSLs? Are they effective? What new resources could be established?

Some participants expressed the view that the pre-college level is where educational systems should begin preparing nanotechnology-literate citizens: training future technicians, scientists, and engineers, and using nanoscale concepts to pique student interest in STEM. NSE has a "wow" factor that gets students excited about STEM and motivates them to learn. However, impediments in the United States to achieving STEM education goals include the fact that each state has its own set of standards and learning goals, and there are significant disparities in standards between states and between individual school districts. The National Research Council (NRC) Board on Science Education (BOSE) has published a conceptual framework for new science education standards that establishes core disciplines of the life sciences, earth and space sciences, physical sciences, and engineering and technology. That framework is the basis for the NRC's May 2012 draft report, *Next Generation Science Standards for Today's Students and Tomorrow's Workforce* (http://www.nextgenscience.org). Unfortunately, nanotechnology is not very prominent in this document, and the nanotechnology community should work to remedy this.

Most participants thought that the importance of technical and community colleges in U.S. science and engineering education was growing significantly, but they face a challenge in addressing their varied missions: workforce training for new high school graduates, preparation of veterans to reenter the workforce, retraining of existing workforce looking to regain cutting-edge skill sets, and lifelong learning for the general public. Each of these missions requires a different course structure. Since employment opportunities vary from region to region and locality to locality, the determination of educational content and specific-subject depth is an essential role for RSLs. NSF has funded a number of NSE community college/technical college programs (Nano-Link, NACK, NEATEC, and Forsyth[23]); these pilot efforts need to be expanded and adopted across the nation.

One point raised was that, although no mandated teaching and learning standards exist at the college level (beyond professional accreditation), strong disciplinary boundaries are reinforced by both the accreditation and competition of departments for funding and resources. These boundaries are often more significant than those at the pre-college level. Nonetheless there has been significant progress in the incorporation of NSE concepts into curricula and textbooks at the college and graduate school levels. Nanotechnology-based courses are being introduced rapidly at four-year colleges and universities. However, a significant challenge is the incorporation of hands-on experience.

Participants commented that the weakest NSE elements in university education involve nanoscience education for students who are not majoring in science or engineering. Incorporating science-related societal issues and other creative interfaces to science education as a component of liberal arts courses would offer opportunities to increase science and technology literacy and advocacy among non-science majors.

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[23] Midwest Regional Center for Nanotechnology Education (Nano-Link), Dakota County Technical College, Rosemount, Minnesota, http://www.nano-link.org/; Nanotechnology Applications and Career Knowledge Center (NACK), Pennsylvania State University, State College, PA, http://www.nano4me.org/educators.html; Northeastern Advanced Technological Education Center (NEATEC,) Hudson Valley Community College, Troy, NY http://www.neatec.org/; Forsyth Tech, Winston-Salem, NC, http://www.forsythtech.edu/credit-programs/credit-track/programs-a-z/nanotechnology.

Many participants thought that the traditional academic disciplines have been quick to introduce nanoscale research that leads to master's and PhD degrees in those disciplines. Nanoscale science and engineering education is most developed and pervasive at this level, with essentially all the research universities engaged. While not unique to NSE, one remaining challenge/opportunity is to develop mechanisms to better match NSE professionals with entrepreneurs. This could be an important activity for RSLs towards helping accelerate the realization of economic benefits to the local community.

4. How can we more specifically define what effective training for nanotechnology-related careers should be and who should have input into that definition?

Some answers to this question in the context of formal educational structures are addressed by the previous discussions. However, while formal schooling is an important contributor to STEM education, most participants agreed that informal venues are also quite important. One example was the Nanoscale Informal Science Education Network (NISE Net), established in 2005 for the purpose of creating and vetting a national infrastructure of informal science education institutions. But this limited number of templates must be adapted to and implemented in the many regional, state, and local venues. Further, in this information age, social media (Wikipedia, Facebook, YouTube, Second Life, etc.) provide new opportunities for informal education that are underutilized.

There are other informal educational mechanisms that can provide effective nanotechnology training beyond traditional structured classes. Science fairs encourage creativity and a sense of personal contribution, helping generate future MSs and PhDs. Science Olympiads and other science challenges involve structured problem solving in a competitive environment (and in 2012, materials science was represented in several such competitions). Middle school science challenge teams are of interest because they more accurately represent the demographics of the entire school than they do at the high school level; involving students at the junior high school level and affirming their interests in technology at that critical age will help with diversity. However, standards-based education seems to be getting in the way, for example by discouraging hands-on experiments. Generally, most participants thought that the earlier nanotechnology is introduced in the educational system, the better.

Session 3. Reducing Uncertainty in the Marketplace: Regulation, Insurance, & Risk Management

Co-Chairs: Richard C. Pleus, Charlie Gause
Notetaker: Sandra Chapman

Background

The ability to manage risks associated with the development of nanotechnology presents considerable challenges. The uncertainty surrounding these risks promotes a tenuous business climate. The nanotechnology business community has had to address some negative public opinion, facing an "upstream public engagement" to an extent not encountered by other technology-driven markets such as the semiconductor and telecommunications industries. As the risks, benefits, and properties of nanotechnology applications are better understood and defined, the industry's current uncertainty will be reduced.

During the 2012 NNI RSL workshop, this breakout session was held to explore the timely and important issues surrounding risk management and definition in the nanotechnology industry. Public and private stakeholders working in this field discussed knowledge gaps, perceptions, and solutions. This group included representatives of local, state, and national entities from both the public and private sectors.

Summary of Questions/Answers

1. In what ways does the current regulatory environment for nanotechnology-related businesses cause business uncertainty?

The most consistent industry response discussed at the session was the concern for the lack of regulations on nanotechnology, and that, if such regulations were developed, they might not be clear. In fact, the "fear" of regulation was thought by commenters at the session to be a more problematic issue for business than the regulations themselves. The key point was that regulations should be science-based, simple, consistent, and clear. Commenters believed that with regulations meeting those criteria, businesses would better know how to prepare and plan for their future. Uncertainty in the nanotechnology industry would thus be reduced. Other comments from this session included the following:

- The regulatory environment appears to be industry-specific. Put another way, some industries have been under greater scrutiny than others. The rationale for this scrutiny differential was not presented.
- Worker safety, particularly in industries producing engineered "nano-objects" and nanomaterials, is a main driver in the EHS arena. However, many session participants commented that most industries have safety programs and engineered mitigation measures, and have consulted with National Institute for Occupational Safety and Health (NIOSH) on best practices for worker safety. These approaches are not regulatory; rather, they are voluntary solutions to minimize worker exposures.

2. To what extent does the current regulatory environment affect business growth?

It was noted that regulations in general have an impact on business decisions. The extent of the impact depends on the industry, the material in consideration, and the regulatory details.

Many participants expressed the view that there is a lack of regulation from an environmental perspective. The Food and Drug Administration (FDA) has been increasingly transparent in discussing how it will assess pharmaceutical and medical devices that have, or are, engineered nano-objects. Some were aware that the Environmental Protection Agency (EPA) has proposed Significant New Use Rules (SNURs) in response to Premanufacture Notices (PMNs) submitted for carbon nanotubes, but that has only been on a company-by-company basis so far.

Another important discussion on this question centered on the issue of labeling. There was a strong consensus that indiscriminant requirements for product labeling would affect business growth adversely. Of the several points as to why labeling proved to be an important topic, the most prominent was that the definition of what would and would not constitute a nano-object would be a major variable. For example, there are many chemicals on the market today that are nanoscale. The process of discriminating between those chemicals that are and are not nanoscale would be tedious and prone to error. That said, it was noted that the European community may move towards labeling; if so, U.S. producers that want to sell products in Europe would have to comply.

3. What governmental actions could reduce such uncertainty?

It was discussed that the greatest way that government entities could proactively reduce uncertainty would be by communicating the benefits and risks of nanotechnology, and by clearly stating how these agencies are working on managing the risks associated with nanotechnology. Commenters were frustrated that some of the “loudest” public voices have claimed that the Federal Government is not paying adequate attention to EHS issues. While one might be able to argue that the government could do more in regards to EHS issues, there is considerable evidence that the government, industry, and nongovernmental organizations are deeply involved in EHS issues. The concern of some participants was over “hype” and “fear mongering” by a small fraction of the public. Some expressed concern that public opinion might follow the example of genetically modified foods, the public perception of which was negatively biased by scientific misinformation. That sort of misinformation should be effectively combated by a concerted governmental effort to clearly communicate the implications of the science and industry of nano-objects. Commenters acknowledged that the EHS science community is motivated and energized to participate in dissemination of correct science-based information.

4. Do you believe that worker safety has been an important issue in the development of particular nanotechnology research or manufacturing facilities?

Many session participants answered this question in the affirmative. In the past, it was believed that industry action has not been motivated by regulatory action(s) per se. Many manufacturing companies voluntarily put into practice engineering controls and adopted best practices to protect workers. NIOSH has also participated in the process. Many participants agree that NIOSH’s program has had positive benefits. Briefly, if NIOSH is invited by a manufacturer, its investigators visit the facility and make an assessment. They offer recommendations as a result of their assessment for the manufacturer to use to work towards mitigation of problems, if needed. There is no cost to the manufacturer.

Commenters noted that there is a difference between the practices of worker safety in industry as opposed to in academia. The concern is that the same standard of implementing best practices, EHS mitigation, and control measures are not well practiced in academia, thus leaving academic workers at potentially greater risk. No specific reasons for this observation were noted.

5. Has the insurance industry helped reduce uncertainty in business? If so, how?

In the public media, the use of terminology that implies harm, such as the statement that carbon nanotubes have "asbestos-like" properties, has raised concern about EHS issues related to nanotechnology objects. As a result, insurance companies have been investigating how to best manage the business risk of nanotechnology companies. Most insurance companies have been publicly silent. Thus, it was observed that it is difficult to assess factually whether the industry is helping reduce uncertainties or not. A few companies have been public about this technology, and a smaller number have been proactive about dealing with it in a public manner. It was noted that insurance industry officials have attended conferences and developed informational pieces that have been released publicly.

6. If the industry has not helped reduce business uncertainty, how could it?

Some commenters felt that the greatest concern driving insurance companies is that EHS issues will become litigation concerns, like asbestos has. As a result, they recommended that the insurance industry join forces with government agencies for more research into EHS issues to clarify risks. The insurance industry could work with the government and with the nanotechnology industry to make them aware of the insurance market and the monetization of possible risks.

7. Does industry have all the risk management tools to allow for safe development of nanotechnology businesses in the United States?

Many commenters agreed that some industries had sufficient risk management tools and that some industries did not. There was no further discussion on which industries fell into which category; however, as noted above, those involved in the manufacturing of nano-objects may have implemented practices, procedures, and engineered solutions to protect workers. Those that are waiting for government to provide regulations may not have implemented all necessary procedures to manage risk.

8. What are examples of risk management tools?

Regarding tools for nanotechnology-related industry, commenters offered a few examples of organizations and documents that have provided approaches to risk management:

- NIOSH has published guidance and publications related to occupational exposures: http://www.cdc.gov/niosh/topics/nanotech/pubs.html.
- The Good Nano Guide, a collaboration of Canadian agencies, NIOSH, and the International Council of Nanotechnology provides information on how to manage risks from engineered nano-objects: http://goodnanoguide.org/tiki-index.php?page=HomePage.

- The Nano Risk Framework by DuPont/EDF provides an EHS framework that provides a process to manage risk to workers and the environment: http://apps.edf.org/documents/6496_nano%20risk%20framework.pdf.
- ISO/TR 12885:2008 describes health and safety practices in occupational settings relevant to nanotechnologies: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=52093&commid=381983.

Session 4. Effective Partnering for an Innovation Ecosystem

Co-Chairs: Griffith A. Kundahl, Mary Jo Waits
Notetaker: Christopher Cannizzaro

Background

Nanotechnology, as an inherently interdisciplinary field, necessitates effective partnering strategies. A variety of partnering strategies and organizational structures have been developed and utilized by RSLs across the United States over the past 10+ years. Some have been successful, and others have not. RSLs have also developed different mechanisms for engaging new stakeholders, empowering nanotechnology champions and ambassadors, and finding and securing funding for their missions. Some models are defined by state boundaries and others organize around other regional boundaries or shared interests.

During the 2012 NNI RSL workshop, an open breakout session was held to explore concepts, methodologies, and issues related to optimizing partnering strategies to facilitate an effective nanotechnology innovation ecosystem. Public and private stakeholders contributed to the discussion from a variety of perspectives. The workshop group included representatives of local, state, and national entities from both public and private sectors.

Summary of Questions/Answers

1. What are the kinds of organizational structures that have worked well for nanotechnology RSLs (e.g., nonprofits, public–private partnerships, etc.), and why? What structures haven't worked well, and why?

Organizations that have been successful are typically those that have clearly identified the strengths of members and constituents and that have defined a value proposition for the community served. Key partners in successful organizations tend to be research institutions, startup companies, large companies, government entities, angel and venture capital organizations, and workforce development and STEM education stakeholders. RSLs that have succeeded tend to establish metrics that provide a measure of progress and also have determined ways to incentivize participation and collaboration. Collaboration takes different forms (i.e., university-to-university or university-to-industry collaboration). The structure and mission of the RSLs varies quite a bit. Examples of different structures were explored, including ONAMI, NanoBCA, and COIN.

Models that tend to have failed in the past include those that omit the collaborative and interdisciplinary component (i.e., university-only, industry-only, volunteer-only structures). It is also clear that sustained funding is a prerequisite for enduring RSLs.

2. What partnering or outreach mechanisms have RSLs utilized to develop stakeholders, champions, and sources of funding?

A primary mechanism required for partnership development is the establishment of a trusted and effective forum, i.e., the RSL itself, such as ONAMI or COIN. The forum itself provides a gathering place for content aggregation and networking across disciplines. The forum also allows for events, deeper engagements, public awareness and media campaigns, colloquia on topics such as entrepreneurship or regulatory issues or financing, and a means for connecting students, whether K–12, community college, or graduate level, with industry and startups.

Another successful partnering mechanism has been the establishment of shared user facilities such as those developed by ONAMI. These facilities provide easy and shared access to advanced microscopy and other critical tools that individual entities, especially startups, often struggle to access.

Mechanisms for facilitating early-stage funding, where available and feasible, also address a critical need: access to capital and traversing the "valley of death."

3. Is regional partnering across state lines a viable model, or should individual states compete instead?

Partnering across state lines has proven to be viable, albeit more difficult. Difficulty arises in establishing equitable funding models and distribution of resources and tasks in multiple jurisdictions that inevitably have varying governance structures and procedures. The New England Clean Energy Council is an example of a successful cross-border collaboration. The search for meaningful synergies often requires partnering beyond traditional borders. Ideally, like-minded organizations in different states will work to establish similar models and best practices that facilitate an easier path to collaboration

Session 5. The Value Proposition of RSL Nanotechnology Initiatives

Co-Chairs: Anthony Green, Egils Milbergs

Background

Recent thinking about advancing the commercialization of innovative technologies has focused on the growth of *regional innovation clusters* as a means to counter existing barriers. These often fall short because they are not organized systematically to leverage the advantages of an innovation cluster. These clusters have been described as geographic concentrations of companies, suppliers, support services, financiers, specialized infrastructure, and specialized institutions whose competitive strengths are synergistic when shared. Comprising academic institutions, research laboratories, small and large companies, economic development organizations, and capital providers, these clusters move technology forward by stimulating business formation and creating jobs.

Barriers to their success include the following:

- Lack of commercialization expertise at many research institutions where innovative technology is born.
- Lack of access to sufficient seed-stage and early-stage venture capital.
- Lack of management talent, workforce talent, and industry-specific talent to create local companies.
- Lack of a systematic innovation partnership between the Federal Government and state and local governments.
- Lack of a "critical mass" of supportive individuals and business in these technology areas.
- Lack of patience among stakeholders, whether corporate or political.

Each of the above barriers is exacerbated by the current economy and subsequent shifts in the technology development pathway. Economic factors include the following:

- Large companies are downsizing or eliminating internal innovation programs, and they rely more and more on smaller companies/universities for new ideas via open innovation strategies.
- Small companies are trapped by the need to find large companies to partner with because the small company's ability to grow is hampered by the current economic climate, combined with:
    - The lack of resources to identify opportunities via either other small companies or technologies developed at research institutions.
    - The lack of experienced entrepreneurs to lead management teams.
    - The lack of capital necessary to reach commercialization.
- Universities and research institutions need better ways to get their technologies to the marketplace; whether it is to a small or large company is irrelevant.

The growth of regional, state, and local Initiatives in support of disruptive technologies such as nanotechnology is a critical element to address these challenges and barriers. The characteristics of a successful program include the capacity to:

- Catalyze industry‑university research partnerships.
- Expand regional innovation promotion for technology commercialization and entrepreneurial support.
- Encourage technology adoption by assisting small- and mid-sized companies in implementing these new technologies.
- Support regional industry clusters through new grant proposals, access to capital.
- Support regional job growth and company creation.
- Build a sustainable community of innovation and economic growth.

Summary of Questions/Answers

1. What specific aspects of nanotechnology RSLs make them attractive investments for states and regions?

Incentives to create or sustain RSLs must be reflected in the benefits accrued to the region, balanced by the time frame for achieving these goals. The focus is on economic growth, with key indicators including Federal leverage, company formation, job creation, and revenue to the region/state. Subsidiary benefits include establishment of new university–industry partnership programs, new alliances and strategic partnerships between and among regions, increased company competitiveness, and extra-regional benefits to rural areas.

However, each of these goals has its own time horizon. Leveraging Federal dollars and creation of new partnerships can be accomplished in a relatively short time, now that there are national models to use as templates. On the other hand, new company formation and the resulting job creation (and the high-paying nature of these jobs), especially in technology companies and in the current fiscal climate, will take considerably longer to pay off.

So, why start an RSL? The discussion identified three areas of benefit, delineated by the time line needed to achieve these benefits:

1. Leveraging Federal dollars (short-term).
   - New intellectual property.
2. New partnership opportunities (short – medium term).
   - Industry/university partnership programs.
   - Technology transfer and licensing.
   - Extra-regional alliances between neighboring initiatives, e.g., Pittsburgh works with Ohio; Philadelphia works with Delaware and New Jersey.
3. Economic return (medium- to long-term).
   - New company formation.
   - Help existing companies be more competitive, grow.
   - Jobs (noting that jobs in the area will be higher-paying).
   - Attract out-of-region companies.
   - Rural benefits (e.g., shale gas, clean water).
   - Sharing investments and benefits across political boundaries.

2. Are there successful case studies that can be used as models?

Several successful programs were highlighted. Importantly, each has its own structure, program elements, and management to allow for efficient local control and maximal regional effect. Equally important, each of these programs has now existed for a sufficient time to accrue validated metrics of performance, including leverage, follow-on funding, company engagement, and job growth. Examples include the following:

- The Center of Innovation for Nanobiotechnology (COIN; Durham, NC): http://www.nanobiotech.org.

- The Oklahoma Nanotechnology Initiative (ONI; Edmond, OK): http://www.oknano.com.
- Oregon Nanoscience and Microtechnologies Institute (ONAMI, Corvallis, OR): http://www.onami.us.
- The Nanotechnology Institute (NTI; Philadelphia, PA): http://www.nanotechinstitute.org.

The breakout session discussion focused on the *key factors in a successful program* and the metrics by which these programs are evaluated or should be evaluated:

- *Funding*: program funding will inevitably be secured from multiple sources—state, region, foundation, university, corporate, etc. However, it was agreed that the most successful programs are able to secure funding from multiple sources: reliance on a single source limits opportunities and sustainability. It is also important to understand clearly any restrictions on the use of funds that may come with funding: funding may be restricted geographically; some funding may not be allowed for specific uses, etc. (e.g., Pennsylvania does not allow its funds to be used for equipment purchases).
- *Leadership*: Each of the programs showcased benefited from highly committed, long-term leadership, recognizing that the success of these programs takes significant effort and time.
- *Recognition of collective good; willingness to share/collaborate*: There is an increased awareness that multi-stakeholder programs benefit most when the stakeholders agree there is a benefit to collaboration and to avoiding insularity.
- *Regional connections*: Programs that leverage their regional assets, technological, business, financial, etc., will have the best chances for success.

3. What information and metrics are required to demonstrate success?

One of the most important challenges for regional technology organizations is to determine the criteria for success, both quantitative and qualitative. While many participants agreed on a core set of metrics linked to commercialization, it was also agreed that a secondary set of metrics is also required that represents interests that are more parochial/regional. Most importantly, these metrics and the defined successes must be communicated effectively in order to establish the value of these programs (see Question 4, below).

Core metrics include:

- Companies formed.
- Jobs created.
- Dollars leveraged.
- Follow-on capital.

Secondary metrics include:

- Intellectual property: patent applications, issued patents.
- Licenses.
- Out-of-region investment.
- Success stories.

4. How have RSLs communicated their value proposition to their stakeholders and funders?

Effective communication of regional value is a common theme among all the issues discussed in this breakout session. Those organizations that succeed in this aspect garner committed investiture by stakeholders. By contrast, those that don't will not succeed. RSLs must be cognizant of the spectra of their audiences and their distinctions. Communicating with academia or industry is different from communicating with the financial community, and each is very different from communicating with the public or government. This is complicated further by the recognition that many programs have not been around long enough to demonstrate value.

The discussion identified several examples of these distinctions:

- *Communicating with academia*. Academia has gone through a difficult evolution to recognize that regional collaboration, as in an RSL, has its benefits, and the key benefits for academia are funding and technology transfer. RSLs must show how they will provide new opportunities to compete for funding, particularly Federal funding, that emphasize multi-institutional collaboration. They need to demonstrate their success in accelerating the commercialization of institutional technology through licenses and startup companies.
- *Communicating with industry*. RSLs must establish a "dialogue with industry" and demonstrate that they understand industry needs and challenges. Equally important, they need to show they can distinguish between the needs of small companies, where the focus is on funding and moving to the next level, and large companies, where the focus is more towards pipeline and identifying new technologies and partnerships or research programs that aim to solve big industry problems. This requires a committed and consistent interaction with industries, i.e., ask them what their problems are, then how nanotechnology can provide solutions. Most important is the need to communicate how *this particular* RSL will help industry.
- *Communicating with the financial market*. Many RSLs do not have direct relationships with the financial markets except through angel investors and venture capital. The key is to manage expectations. This is not a novel concept and is an issue with all technology development. It was no surprise that the early years of nanotechnology were harmed to some degree due to over-investment based on "buzz." Investing on the buzz can lead to great things or it can lead to nothing. The capital required to be successful, the timeline to achieve this success, and the return on investment—in the end, all must reflect economic realities: successful commercialization of a nanotechnology-based product will almost always cost more and take longer than anticipated by the entrepreneur. Companies do not have the financial safety nets of the past, and the days of venture portfolio returns of 10:1 are long gone.
- *Communicating with government*. Many RSLs are funded by local or state agencies, and the need to communicate with decisionmakers is paramount. Making an effective case for an RSL requires recognition that agencies have multiple priorities and multiple requests for funding. Legislators are motivated by political realities. Moving an RSL higher in priority requires demonstration of

successes—success stories, “show-and-tell,” and stakeholder advocacy. There is nothing more effective than company managers talking to legislators and stating that their company is here, successful, paying taxes, and hiring more well-paid workers because of the efforts of the RSL.

- *Communicating with the public*. New technologies can be made or broken by how well the benefits and risks of these technologies are communicated to the public. For every biotechnology, there is a “genetically modified organisms” (GMO) public relations risk. The hype of nanotechnology during its genesis resulted in its corollary: public fears of an emerging technology. In the early years of nanotechnology some people raised many of the same fears as had been issues with GMOs, threatening its viability. Concerted action over the past several years has diminished the problem, but it has not been eliminated. Many participants agreed that all stakeholders must be vigilant, provide effective and responsible leadership, and provide ongoing education and outreach to the general public.

5. What strategies are available to accelerate collaboration?

The discussion identified four key components for successful collaborations:

1. *Create a culture of collaboration*. Using the four initiatives listed above (COIN, ONI, ONAMI, and NTI) as templates, note that each is comprised of multiple stakeholders: academia, industry, government, and economic development organizations, all with a vested interest in the region. Affiliation and interaction with providers of physical space—incubators, science parks, etc.—are also important contributors. Each initiative also recognizes the need for and benefits from active collaboration and agreement that collaboration will be synergistic, not competitive.
2. *Get businesses engaged*, as well as trade associations and high-tech groups, to promote the idea of open innovation, all seeing the opportunities from technology-based economic development.
3. *Reach out to SMEs*, not just big companies. Many initiatives fail because of a singular focus on large company involvement without recognizing that it is often the emerging companies that drive innovation and job growth.
4. *Focus on rapid response teams for SMEs*. Given the current economic climate, emphasis must be placed on small companies, and RSL organizations must be prepared to help nurture these companies. This goes beyond funding and includes assistance for company growth, management, securing follow-on funding, help with grant applications, business plans, etc.

6. What policies are required to assure the success of nanotechnology RSLs?

RSLs do not work in a vacuum; the successes of the initiatives and their stakeholders are inextricably bound up in the policies that affect each organization, in terms of both opportunities and constraints. At the same time, RSLs can play an important role to define and communicate policies of particular interest. The discussion identified several key recommendations:

- *Provide a mechanism for RSLs to speak up about taxes and incentives*. RSLs cannot be silent and must be vigorous advocates for their stakeholders. In the current economic climate, with shrinking dollars for grants from states and regions, RSLs must be aggressive in communicating their message. Currently, there are limited opportunities for RSLs to present their cases to those who provide funding, create tax policy, and define incentives.

- *Allow R&D tax credits for collaboration*. This interesting recommendation goes beyond typical tax credits for R&D, often available to most companies through state tax policies.
- *Allow angel financing tax credits*. Many states are now looking to increase tax credits for angel investors, and it is clear that the companies within RSLs will be direct beneficiaries of these credits. Changes in government policy for SBIR/STTR eligibility with regard to angel and venture capital investment in small companies is a step in the right direction.
- *Open up eligibility requirements for commercialization-oriented programs*. A number of new initiatives, particularly at the Federal level, have emerged over the past couple of years, including the Economic Development Administration's i6 Program and NSF's Accelerating Innovative Research and I-Corps programs. Unfortunately, many of the RSLs are ineligible to compete for this funding, either because they are not degree-granting institutions (e.g., the NSF Accelerating Innovation Research Program) or not legal entities (e.g., not a 501c[3]).
- *Establish new self-financing mechanisms for regional innovation clusters*. There was recognition that most RSLs will not be sustainable from current funding mechanisms, and that opportunities and new strategies must be established with a focus on mechanisms for industry to contribute to clusters.

7. What barriers exist that impede the success of nanotechnology RSLs?

Three key barriers were identified as challenges to the success of RSLs:

1. *Inadequate funding*. This issue will never go away. As discussed above, it will be difficult for any RSL to be fully sustainable without significant and diverse sources of funding. Opening up opportunities for new sources of funding (see above) will go a long way toward helping secure financial stability.
2. *Long time horizon*. Most participants agreed that lack of patience is a significant barrier to success. This derives from the lack of understanding about the time horizon for any new disruptive technology. Whether it is semiconductors, biotechnology, or nanotechnology, it still takes about 20 years for a new technology to mature. We are only in about year 10 for nanotechnology. The fact that nanotechnology is right on track is no comfort to those who insist on instant success. Whether it is an investor who wants a rapid (and multiple) return on investment, legislators who need immediate success to showcase before the next election to provide critical political support for funding, or members of the public who expect tangible benefits in a short time, the common missing element is patience. This is not something RSLs are going to solve, but through effective communication and better education of the populace, these issues can potentially be mitigated.
3. *Fear of the unknown and communicating risk*. Every disruptive technology has gone through periods when public imagination about the potential

harms of the new technology exceeds reality. Biotechnology, genetically modified organisms, and now nanotechnology have all suffered from initial hysteria, with protestations of dire consequences to come. Over-promising about the likely impact of these new technologies by scientists, companies, and the media can contribute to this hysteria and create a serious challenge to the success of any new technology. Effective communication supported by rigorous science can help counter this behavior.

Keynote: How Innovation Enhances American Competitiveness

Brian Markwalter
Senior Vice President of Research and Standards,
Consumer Electronics Association

Today, innovation is driving U.S. competitiveness, especially in the consumer electronics industry. Innovation defines our competitive edge and is the key to economic success in the United States, where it not only creates jobs but entirely new industries.

There are three major obstacles to U.S. innovation today that the Consumer Electronics Association (CEA) is working to remedy. First, the government needs to get out of the way of small businesses and let them prosper. Second, the United States needs a trained workforce with the right technical degrees. Third, the United States needs to reform immigration policies to encourage new graduates to stay in the country. If the United States focuses on policies that spur and support U.S. entrepreneurs and innovative companies, it will help maintain U.S. economic dominance and prosperity.

At the 2012 International Consumer Electronics Show, CEA's goal was to host 30 new startups, but instead had 102 exhibits. For the 2013 International Consumer Electronics Show, CEA is setting aside space for 140 startups in its Eureka Park TechZone, a dedicated area showcasing innovative startups and entrepreneurs. CEA was set to sponsor the June 2012 Eureka Park Challenge contest for a free exhibit space at the 2013 International Consumer Electronics Show, to be determined in a live on-stage presentation. After submitting innovative technology products and services for online judging, ten finalists would be featured within a two-day interactive exhibit area at the 2012 Consumer Electronics Week in New York City.

See http://www.ce.org/ for more information on the Consumer Electronics Association.

CHAPTER 6

Day 2 Introductory Presentations

Day 2 Welcome by Jim Kadtke

Jim Kadtke observed that the previous day had produced a wealth of ideas and background about nanotechnology RSLs and the challenges and opportunities they have. Several key points included Clayton Teague saying that a roadmap for national coordination of RSLs would be a valuable undertaking; Ted Wheeler pointing out that collaboration is needed between the public and private sectors because they work under different incentive systems; Jim Mason urging the nanotechnology RSL community to get together more frequently and calling for Federal funding to support nanotechnology RSLs; Mark Skinner saying there was a real need to make technology-based economic development more relevant to society as a whole, so that there are better incentives for them to invest; and Ed Cupoli suggesting that developing detailed case studies about particular RSLs would provide valuable data for further business and policy analysis.

On this second day of the workshop, the morning session was devoted to industry and business concerns, while the afternoon session was focused on forward-looking issues, namely, what things could be done to improve the environment and health of nanotechnology RSLs in the future. In particular, the roadmapping café breakout sessions were brainstorming sessions to explore new options and mechanisms to aid RSLs.

Comments by Senator Jeff Merkley

Senator Merkley (D-OR) expressed appreciation for the critical work that RSLs do to advance innovation in the United States. He grew up in a working-class Oregon community and is concerned about the recent loss of manufacturing activity and the good family wage jobs that it supports. Multi-agency Federal programs such as the National Nanotechnology Initiative and the new Advanced Manufacturing Partnership, in collaboration with local institutes such as ONAMI, hold promise for improving this situation.

Keynote: A Co-Innovation Business Model: Lessons from an Industry Perspective

Samuel G. Angelos
Vice President and General Manager, Technology Development Operations, Hewlett-Packard

Samuel Angelos opened his talk with the question "Is co-innovation the new open innovation?" Co-innovation is defined as when "two or more companies work together (partner) to solve a problem, invent something new, and/or launch a new product, process, or concept." Three case examples from HP's Corvallis, Oregon, operations are illustrative:

1. Multicomponent oxide display backplane electronics were co-developed with Oregon State University (the transparent electronics research group) and multiple display manufacturers. The benefits are sharper and brighter images for large displays, greater voltage stability over life, and lower-cost manufacturing.
2. Very-high-efficiency solar cells were co-developed with DARPA and a manufacturing partner. This disruptive approach to leveraging high-volume plastic and optics to focus energy (250 suns) to the photovoltaic device (the most expensive component) yields 25 - 35% efficiency in a low-cost, scalable design.
3. Microelectromechanical systems (MEMS) inertial sensing technology is being co-developed with Shell Oil to greatly improve the speed and cost of seismic mapping.

Lessons learned from many years of successes and obstacles encountered in these complex co-innovation programs can be summarized in terms of ten success factors, organized into four groups:

1. Internal Factors:
   a. Shelter the project from internal metrics and processes.
   b. Banish supplier/procurement thinking.
2. Partnering:
   a. Have the tough conversations up front.
   b. Negotiate based on principles.
   c. Never overestimate your knowledge of your partner.
3. Value Creation:
   a. Every decision needs to improve risk-adjusted value.
   b. Communicate your vision (prepare the market, build your brand).
4. Market Disruption:
   a. Market disruptions are often driven by technology innovation.
   b. New businesses fail for commercial reasons.
   c. The more outrageous the vision, the more resilient the program.

Figure 6.1 summarizes the key factors characterizing four different innovation models (per Frost and Sullivan).

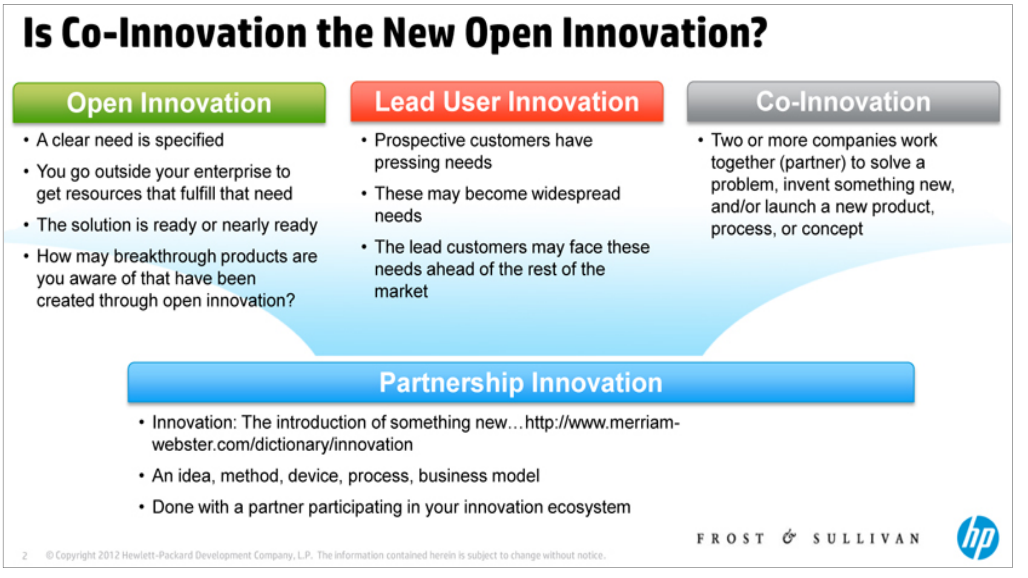

Figure 6.1. Key factors of four innovation models (© 2012 Hewlett Packard).

CHAPTER 7

Session C: RSL Best Practices, Business Models, and Partnering Mechanisms

Plenary C-1: Partnerships: Driving the Materials Revolution

Travis Earles

Senior Manager for Advanced Materials and Nanotechnology Initiatives, Lockheed Martin

Travis Earles gave a large corporation's perspective on the development and deployment of nanotechnology products. Mr. Earles' experience with nanotechnology was also strongly informed by his previous experience as the Assistant Director for Nanotechnology at the White House Office of Science and Technology Policy.

Lockheed Martin (LM) is a huge corporation with almost $46 billion in annual revenues and 126,000 employees worldwide. LM started a major effort in nanotechnology in 2007. Today LM is developing a wide range of nanotechnology solutions across its four main business areas: aeronautics, electronics, space systems, and information systems. Revolutionary nanotechnology solutions being developed by LM are summarized in Figure 7.1.

Nanotechnology solutions are being integrated into different business lines by the Lockheed Martin Advanced Materials / Nanotechnology Integrated Product Team (AM/N IPT), with over 150 participants across 10 different working groups. The AM/N IPT is central to the corporation's capability to lead innovation and drive transition of nanotechnology across core platforms and into adjacent market spaces.

One example of advanced nanotechnology-enabled materials is APEX, a lightweight nanocomposite that leverages low-cost manufacturing processes to create affordable solutions for complex designs. APEX has enhanced mechanical properties, thermal stability, and electrical conductivity, and maximizes design flexibility by being compatible with multiple manufacturing processes. APEX has been approved for insertion on the Joint Strike Fighter (F-35) wingtip fairings beginning in 2013.

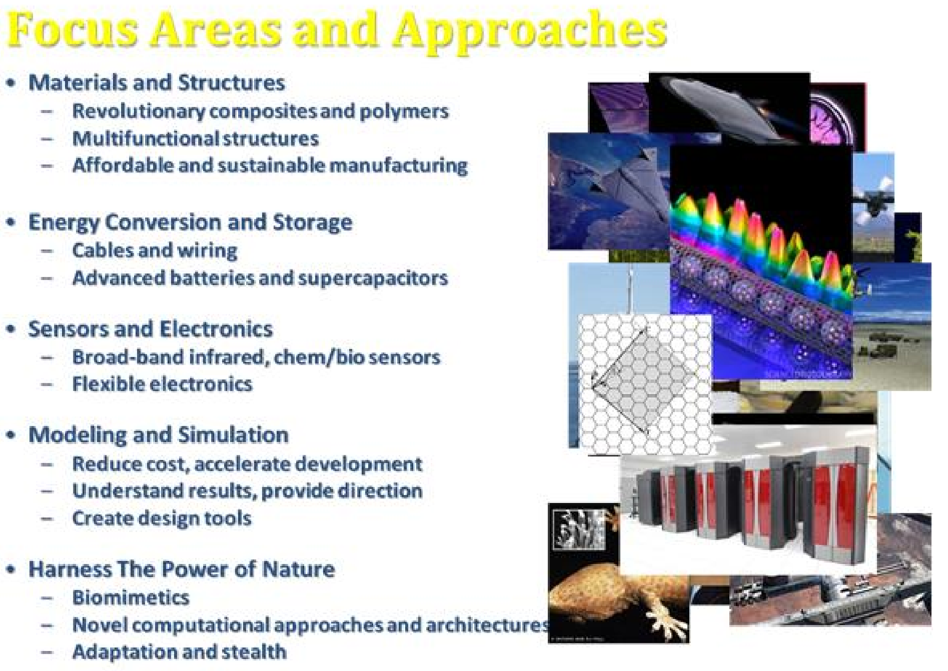

Figure 7.1. Examples of nanotechnologies under development by Lockheed Martin.

One key to LM success in nanotechnology and advanced materials development has been its many and diverse partnerships with government, academia, and other organizations. Its involvement in government partnerships includes the Materials Genome Initiative, the Advanced Manufacturing Partnership, the National Network for Manufacturing Innovation, and the NNI Sustainable Nanomanufacturing Signature Initiative. Academic partnerships include collaborations with the LM Advanced Nano Center of Excellence at Rice University; the MIT Energy Initiative, Media Lab, and Deshpande Center; the Pennsylvania State University Electro-Optics Center; the University of Pennsylvania Regional Nanotechnology Facility; and the University of Texas at Austin Engineering Research Center for Nanomanufacturing Systems. LM is also involved in consortia such as the American Chemistry Council Nanotechnology Panel, the Jordan Valley Innovation Center at Missouri State University, the National Digital Engineering and Manufacturing Consortium (NDEMC) Midwest Manufacturing Initiative, the NanoTechnology Institute, and the NanoMaterials Design & Commercialization Center. Such partnerships play a major role in LM's development of cutting-edge nanotechnology products.

Plenary C-2: Best Practices for Innovation

Mary Jo Waits

Director of the Economic, Human Services & Workforce Division
National Governors Association

The Economic, Human Services & Workforce Division of the National Governors Association (NGA) works with states to identify, share, and implement best practices for efforts such as preparing strategies to support innovation, fostering cluster-based economic development, and facilitating innovative entrepreneurship. The NGA Chair's Initiative for 2011‑2012 is a program of study called "Growing State Economies," focusing on how states can use innovation for economic development. Many states have started their own R&D funds, are using innovation as a policy framework for economic growth, and are pioneering new intermediary organizations to bootstrap specialized innovation ecosystems. These innovation ecosystems have a number of key elements:

- Institutions that attract and support people with the talent and foresight to create new ideas.
- Industry networks that encourage interaction and help develop specialized services that support area companies.
- Facilitation of entrepreneurship to commercialize ideas and build businesses.
- Cultural and social amenities to improve quality of life and attract knowledge workers.

NGA's Strategic Framework for Innovation, described in a 2007 NGA report *Investing in Innovation,*[24] hypothesizes that innovation occurs best at the intersection of four key elements, as summarized in Figure 7.2.

There are ways in which these elements can be developed or enhanced. States or regions can build expertise by creating strong research capabilities and attracting world-class talent in strategic areas. They can facilitate interaction by requiring collaboration among universities and other institutions, cultivating strong networks, creating shared research facilities and compact geographical areas. They can increase diversity by linking diverse knowledge fields and industry sectors using multidisciplinary institutions, well-designed research facilities, and mixed-use research parks to ensure that creative "sparks fly." And finally they can push the application of knowledge and commercialize research by experimenting with university–industry partnerships, pioneering open IP policies and faculty tenure changes, and keeping industry engaged.

There are now some experiments being done by states with new organizational entities that try to improve innovation activity. Figure 7.3 is a notional graphic of an innovation ecosystem. One question is what kind of organizations could fill the role at the center, namely the intermediary function.

[24] http://www.nga.org/files/live/sites/NGA/files/pdf/0707INNOVATIONINVEST.PDF

People studying innovation note four components of an innovative place—whether a company, research facility, or state:

- **Expertise**. New discoveries, new knowledge, and new insights come from smart people who are given the resources necessary for success.
- **Interaction**. Face-to-face is still very important for the exchange of ideas and synergy that create new business models, marketing plans, or products.
- **Diversity**. Ideas will only get better when they are openly discussed and considered by a mix of people with a variety of research fields, backgrounds, approaches, and mind-sets.
- **Application**. Ideas are useless unless used. The true proof of their value is in commercialization.

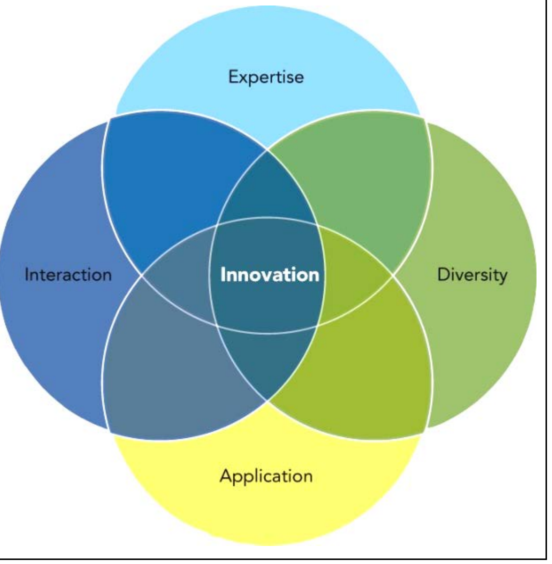

Figure 7.2. Strategic framework to drive innovation (Sources: *Investing in Innovation*, National Governors' Association, 2007, and Pew Center on the States).

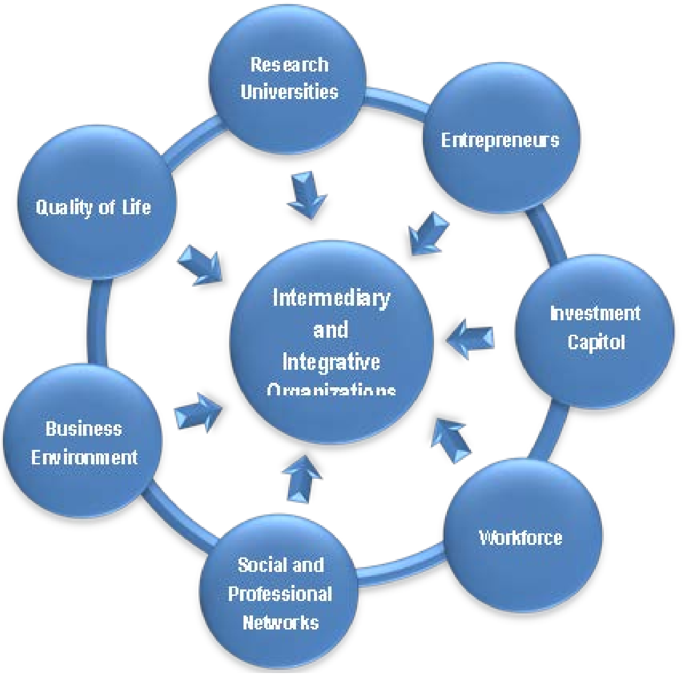

Figure 7.3. Key elements of innovation ecosystems (Mary Walshok, 2010).

Perhaps the most promising model so far for the intermediary organization is what the NGA has termed Institutes of Collaboration (IOC). The elements of an IOC are as follows: they are not part of one university, but sit at the nexus of multiple universities; innovation is their core mission, and they seek to create a local ecosystem of people, institutions, and companies that all support the innovation process; they build an innovation ecosystem for a particular industry cluster, potentially based on resources already available in the state; and they depart from traditional university technology transfer efforts by focusing on what is required "upstream" to bring new ventures out "downstream". These organizations require leaders skilled at networking across traditional boundaries, flexibility in working with industry, an industry focus to target specific sectors that are promising to a region, and facilities that cross traditional boundaries, such as shared user facilities.

In addition to ONAMI (described elsewhere in this report), perhaps the best examples of IOCs right now are the California Institutes of Science and Innovation, which include the California Institute for Quantitative Biosciences (involving the University of California campuses at Berkeley, Santa Cruz, and San Francisco); the Center for Information Technology Research in the Interest of Society (involving the University of California campuses at Berkeley, Davis, Merced, and Santa Cruz); the California Nanosystems Institute (involving the University of California campuses at Los Angeles and Santa Barbara); and the California Institute for Telecommunications and Information Technology (involving the University of California campuses at San Diego and Irvine). The NGA will discuss Institutes of Collaboration in a forthcoming NGA report, *Innovation Begins in the States*.

Metrics are critical to assessing the success of innovation efforts. Figure 7.4 summarizes a framework for and examples of innovation metrics.

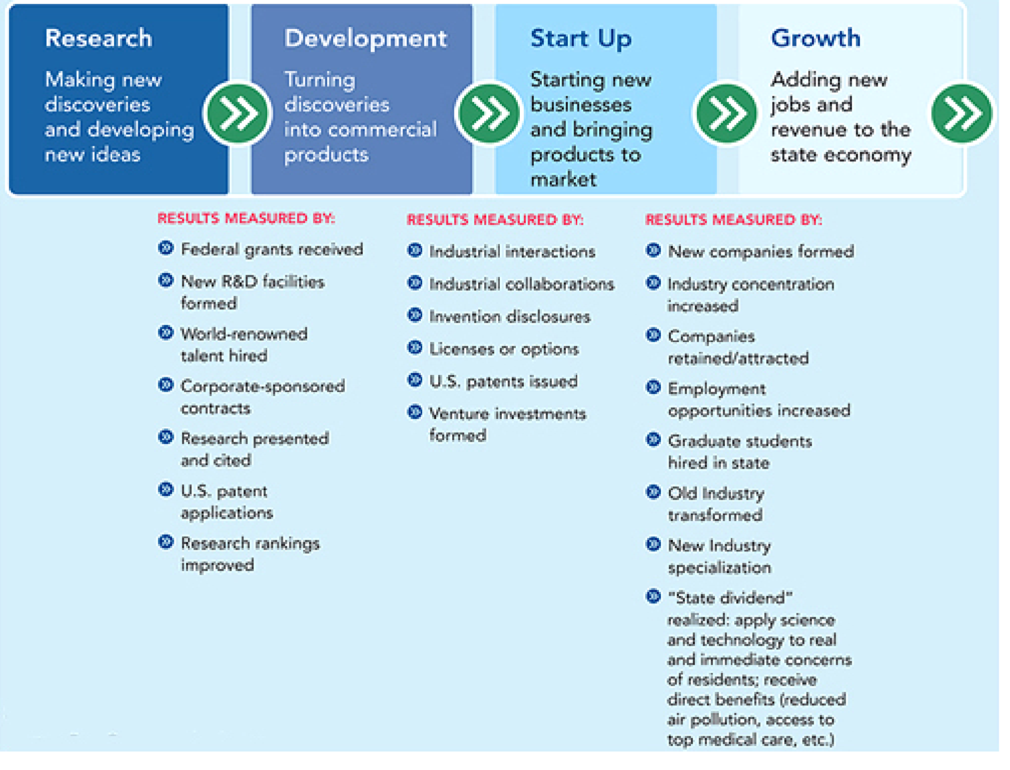

Figure 7.4. Measuring results along the innovation continuum (*Innovation America: Investing in Innovation.* Washington, DC: National Governors Assn. and Pew Center on the States, 2007, p. 58).

Panel Session C: Forward-Looking Problem Solving, Improved Models, and Policy & Legislative Proposals for RSLs

The workshop's third panel session was intended to examine some of the forward-looking issues and actions that could be taken to improve the success rates and economic outcomes of RSLs. The panel was moderated by Jeff Morse of the University of Massachusetts at Amherst, who is also the managing director of the National Nanomanufacturing Network (NNN). Five representatives of nanotechnology stakeholder organizations gave presentations on some widely varying issue areas that could positively impact the U.S. nanotechnology community in the future.

Panel Overview

Jeff Morse

University of Massachusetts at Amherst

In looking at the future of RSL initiatives in nanotechnology, it is important to consider history. In this respect, information and data regarding partnerships, problems, successes, and operational issues can be used to forecast prospects for new and existing RSL approaches, thereby providing improved models that enhance the impact of the initiatives. Looking forward, it is imperative to establish a roadmap for RSL initiatives that takes into account what has been learned from past and present initiatives, and that further incorporates information specific to the locale or region being considered. Information and analysis could include aggregated annual performance data on RSLs, and should include strengths, weaknesses, successes, and failures in order to develop and refine models. In addition, roadmaps and models for RSLs must consider gaps that differentiate many of the initiatives and that could actually contribute to the performance of the RSLs. Examples of gaps to consider may include geography, location, and industry sectors participating, and should lead to a diversified RSL model that may extend beyond nanotechnology.

Successful implementation and execution of RSLs should also consider future opportunities and initiatives such as the proposed National Network for Manufacturing Innovation (NNMI), envisioned as a consortia-based, long-term public–private partnership targeting specific industry and technology sectors and advanced manufacturing. In the context of the NNMI, nanotechnology and nanomanufacturing may be a specific focus of an institute, or more likely components of a broader-based initiative. Such initiatives now come with specific targets for sustainability, led by the value proposition of the consortia and impact to U.S. competitiveness. These objectives are consistent with RSL initiative objectives. Further aspects must consider the relevant policy and legislative landscapes, where nanomaterials and nanotechnology are gaining unprecedented attention from both an economic impact and public safety regulatory perspective. From this standpoint, RSLs have an opportunity to benefit both the public sector and industry base in providing unique assets to better understand the societal implications of nanotechnology, and can lead by example in a proactive and responsible fashion.

Panel Presentation 1
Ms. Deb Newberry

Dakota County (MN) Technical College

Education and workforce training are essential components of an RSL initiative in nanotechnology because they provide knowledgeable workers with core skills that can make an immediate impact on companies engaged in nanotechnologies. The majority of nanotechnology expertise resides currently in the graduate degree programs across the United States, whereas a workforce training mission will require fundamental concepts in nanotechnology to begin in the K–12 stages. It will also require nanotechnology education programs to be offered in two-year and four-year certified degree programs to provide a fundamental understanding of and hands-on training in use of tools and techniques needed for understanding the science. In this context, Dakota County Technical College (DCTC) has established a 2-year Nanoscience Technology A.A.S. Degree Program in partnership with the University of Minnesota, and with industry input it has developed a curriculum that combines nanoscience and traditional science concepts in application areas including nanomaterials, nanobiotechnology, and nanoelectronics. This program has grown into a regional nanotechnology education initiative, Nano-Link, which includes state and community colleges from 5 states.

As nanotechnology education initiatives are further developed, the multidisciplinary aspects of nanotechnology must be taken into account. In order for this to happen, there must be consistency in the fundamental concepts and definitions taught in the available curriculum, while some level of customization must be considered based on the needs of the regional industry and economy. Nano-Link addresses these issues through tutorial “Nano Summits” for industry, providing hands-on, individualized, guided, comprehensive educator training and materials, and outreach through partnerships with science museums and public speaking in civic organizations. Further implementation of nanoscience education must consider a broad-based outreach in which companies are educated about specifics of nanoscience and related educational opportunities through easy-to-understand, generic information, possibly through something like http://nano.gov, for example, in which a single, cohesive “Intro to Nano” document is provided. Such an outreach document could be readily tailored to specific industry sectors, providing additional information such as case studies, stories, examples, directories, and mentors. Additional outreach could be through trade shows, ads in trade magazines, and also soliciting expert students in nanotechnology programs to write market assessment columns for trade journals

For educators, there is a need for easily understood, nanotechnology-based standardized information materials, with some guidance for integration of nanotechnology content within the existing educational curriculum. This could be further complemented by a cohesive, complete, and certified repository of educational content for educators, and a more informal repository for the general public.

Panel Presentation 2
Richard Pleus
Intertox, Inc.

Environmental, health, and safety issues are a critical component of global commerce, with nanoEHS representing a particularly complex scenario, since the amount of information available to appropriately assess the possible exposure scenarios to nanomaterials is limited. As such, there remains a significant need for reliable scientific data to make informed decisions. Thus, an important facet of, and significant opportunity for, RSL initiatives is the development of such data in a manner that is timely, cost-effective, and responsive to commerce.

Currently, there are several resources that have been formed to proactively aggregate and assess scientific data about nanomaterials for informed decision making. One example is the Web-Interfaced Nanotechnology ESOH (Environment, Safety, and Occupational Health) Guidance System (WINGS), an initiative funded by the U.S. Air Force to establish a multicomponent decision analysis web interface tool. Another is the Nanosafety Consortium for Carbon (NCC), whose initial purpose is to address global legal, regulatory, environmental, health, and safety issues related to the responsible commercialization of its members' nanotechnology-related products. NCC includes 13 SME member companies that have teamed together to address EHS and toxicity concerns for carbon-based nanomaterials, and have proposed a six-tiered approach to work with the EPA in acquiring the materials information and knowledge required to establish the necessary regulatory guidelines for these materials systems. Further coordination on materials databases and information assessment tools will enable an information-based approach to future regulatory and legislative requirements that would positively impact the nanotechnology community.

Panel Presentation 3
Anthony Green
Director of the Nanotechnology Institute, Ben Franklin Technology Partners/SEP

Ben Franklin Technology Partners (BFTP) is a technology-based economic development organization that invests in the transformation of the Pennsylvania economy through technology, innovation, and strategic partnerships that foster a favorable business environment for high-growth companies. The BFTP strategy includes seeding, linking, and leveraging of the innovation assets of the region to create companies, jobs, new commercial products, and economic growth. The BFTP model includes effective pipeline building and capital management, as evidenced by its investments in southeastern Pennsylvania representing 61% of all seed/early stage companies funded in this five-county region. BFTP has further leveraged regional innovation clusters and has partnered with technology transfer organizations at leading regional universities and institutions to form, in the year 2000, the nation's first organized regional partnership to accelerate nanotechnology commercialization—the Nanotechnology Institute (NTI)—which includes 13 member

Institutes in the region. NTI is guided by a unique legal agreement that includes a common confidential disclosure agreement (CDA) covering both Individual and corporate concerns; a NanoCommercialization Group; a collaboration agreement (MOU) on IP; and an overarching governance for invention and license procedures, joinder agreements, inter-institutional agreements, and revenue-sharing agreements. NTI has had a significant impact on the regional economy, as demonstrated by the number of jobs and startup companies created and by licenses granted from the member institutions.

Table 7.1 illustrates the historical success of NTI. Table 7.2 demonstrates how successful the NTI has been in comparison to the Von Liebig Center at University of California San Diego (UCSD) and the Deshpande Center at the Massachusetts Institute of Technology (MIT). NTI provides a highly effective RSL model when compared to other notable innovation centers within the United States.

Table 7.1. BFTP NTI Historical Performance Metrics

Category		2000-2007	2008-2010	Total Since Inception
IP Assets	New Disclosures	169*	215	740
	Patent Applications		180	
	Issued Patents		21	
Licenses (including Option)		12	26	48
Startup/Spin-Out		11	14	31
Jobs Created/Retained		NR**	132	>150
Businesses Assisted		NR	43	60
Follow-on Funding/Leverage		$160M	$95.6M	$280M

* IP Assets not broken out during this time period
** Not Reported

Table 7.2. Comparison of NTI to Von Liebig and Deshpande Centers (Input/Output)

	Von Liebig Center	Deshpande Center	NTI
Location/affiliation	Jacobs School of Engineering, UCSD	School of Engineering, MIT	13 Southeastern PA Research Institutions + BFTP/SEP
Initial funding	$10,000,000	$17,500,000	$9,000,000
Source	Gift from the von Liebig Foundation	Gift from Jaishree and Gururaj Deshpande	PA Department of Community and Economic Development
Grant sizes	Seed Grants: $15,000 - $50,000	Ignition Grants: up to $50,000; Innovation Grants: up to $250,000	Up to $120,000 for individual projects; $750,000 for multi-institutional projects
Number of funded proposals	82	80	116
Total amount of grants awarded	$4,600,000	$11,000,000	$16,744,492
Number of licenses	>6	>20	48
Number of startups	26	23	31
Number of jobs created/retained	>180	>400	>130

Panel Presentation 4
Matt Laudon

Executive Director, Nano Science and Technology Institute (NSTI)

Nano Science and Technology Institute (http://nsti.org/) was chartered in 1997 to promote and integrate "small technologies" through education, technology, and business development. NSTI accomplishes this mission through continuing education programs, scientific and business publishing, and community outreach.

In support of the White House directive for an increase in commercialization of American innovation, NSTI has been looking at various commercialization models to accelerate the commercialization of technologies coming out of the National Nanotechnology Initiative, and on a larger scale, to support models for the entire Federal agency system. Over the last four years NSTI, with its partner organization TechConnect (http://www.techconnect.org/), has run technology-to-corporate commercialization programs in partnership with the OSTP, DOE, ARPA-E, DOD, the U.S. Navy, U.S. Army, U.S. Air Force, and the U.S. Pacific Command.

In 2010 NSTI, in partnership with OSTP, produced the National Nanotechnology Innovation Summit and Showcase, in which over 100 commercial success stories were presented or showcased to the attending community. It is NSTI's belief that the ability to track the commercialization history of each funding action associated with the NNI is beyond the capabilities of any agency or private organization. Instead, based on both NSTI's past work with the NNI and its current work with multiple agencies, the NNI should support the creation of an annual "snapshot" of industry-selected, commercially viable innovations that have reached an actionable stage of their development. Each NNI partner agency could encourage its awardees to participate by submitting their commercially viable technologies to the program. Regional cluster support would also encourage RSLs to submit their top technologies into the program.

NSTI plans to host "snapshots" of commercial successes tied to the NNI at an annual event based upon the multi-agency structure used for the 2010 NNI summit. All accepted innovations will be included in a commercialization accelerator program placing them in one-on-one meetings with corporate and investment partners. This program would be structured to support the NNI by annually spotlighting commercially viable nanotechnology-based innovations as determined by a committee of industry and investment advisors. The first of such events will be held in Washington, DC, in the spring of 2013.

Panel Presentation 5
Ross Kozarsky

Nanotechnology Analyst, Lux Research

It is important to consider that nanotechnology is not its own industry or market but rather an enabling technology that enters and enhances many different industry value chains. The impressive performance of the nanomaterials sector alone isn't enough to drive nanotechnology as a market; instead, researchers must develop applications, providing ready-made solutions to address existing market needs. “Nano-intermediates” command over twice the profit margin of nanomaterials (14% vs. 7%). To ensure success in commercialization of nanotechnologies, researchers and entrepreneurs must leverage their core expertise with intimate knowledge of the marketplace. One way of ensuring this is forming partnerships in the early stages.

From the standpoint of effective commercialization of nanotechnology, “nano” is not enough; nanomaterials must compete with incumbent technology solutions. Nanotechnologies need to compete on cost, performance, availability, recyclability, reliability, EHS, and compatibility with existing infrastructure. Value chain positioning is also critical; nanotechnology developers need to become very knowledgeable about their target markets. There is a huge and potentially profitable opportunity to incorporate proprietary nanotechnologies into existing manufacturing lines; incremental improvements within existing value chains have much greater chances of success than total overhauls. Industry-specific dynamics can both spur and slow adoption, and developers need to strike the right balance between building their brands versus driving volumes. The takeaway again is that partnerships are critical. Nanotechnology developers must assure a customer base at every step of development, and continuously consider alternative approaches, such as first focusing on end-use applications and then working backwards.

Keynote: Nanotechnology – A Global Perspective

Don Kania
President and CEO, FEI Company

Don Kania gave examples of FEI’s globally and technically diverse customer base, including semiconductor R&D and manufacturing in Hillsboro, OR; Nobel prize-winning research on quasicrystals at the Technion in Haifa, Israel; protein science in Shanghai, China; and mineral analysis for oil and gas wells in New Guinea.

FEI’s global engagement offers a perspective on nations and institutions that are leading or lagging in their investment and national commitment to nanoscience research. Notable leaders currently include China, which in 2011 overtook the United States as FEI’s largest-revenue country and represented 12% of FEI’s total materials science tool sales, whereas in 2006, sales to China were negligible. Other notable examples came from Germany’s Ernst Ruska Center, Poland’s AGH University, the King Abdullah Institute of Science and Technology in Saudi Arabia, and the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory, which—together with FEI—developed the world’s highest (0.05 nm)-resolution transmission electron microscope.

Investment in science in the United States is waning in comparison to rapid science and technology investment growth in countries such as South Korea, Brazil, Singapore, and Malaysia. This is evidence that emerging nations continue to see, and act on, nanoscale science and technology as a path to economic advancement.

CHAPTER 8

Session D: RSLs and Future Economic Growth—From Concept to Action

Plenary D-1: Nanotechnology Funding: A Global Perspective

Tim Harper
Cientifica, Ltd.

Cientifica runs an annual survey of nanotechnology funding around the world, looking at both government and private funding. They do this to try to understand not only the absolute funding numbers, but also what stage the funding is at, e.g., early-stage infrastructure or more mature operations research funding.

Government funding is vital to launch new technologies because the development period of many emerging technologies can be 10-15 years before they become sufficiently mature to attract commercial funding. In the last 11 years, governments around the world have spent over $67.5 billion on nanotechnology research, with an additional estimated $183 billion coming from the private sector (although the private sector figures have a greater margin of error due to varying definitions of nanotechnologies).

The chemical industry has been the largest sector in terms of producing nanomaterials, but as applications of nanomaterials mature, other higher-value-added applications such as healthcare are beginning to drive market growth. The aggregate spending on nanotechnology research by global region is shown in Figure 8.1.

In dollar terms, China is spending half as much as the United States on nanotechnology research, but when adjusted for purchasing power parity (PPP) the amounts are similar. However, when we determine a country's ability to commercialize emerging technologies (based on factors such as quality of scientific institutions, global competitiveness, capacity for innovation, corporate R&D spending, quality of STEM education, and government procurement of new technologies), Germany, Japan, and the United States score highest, with China on a par with the average of the European Union. Figure 8.2 shows this PPP-adjusted nanotechnology funding expenditures for several countries and regions.

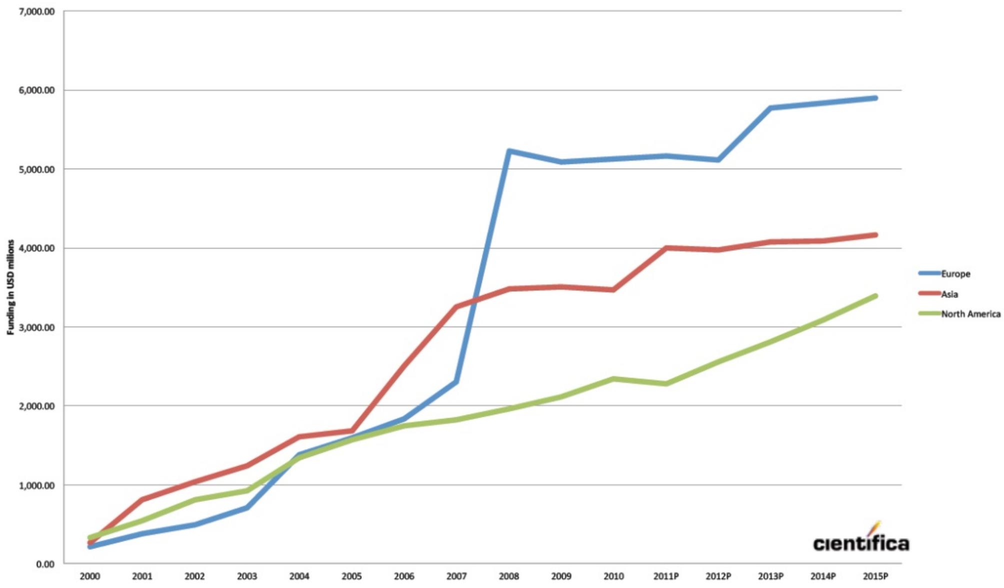

Figure 8.1. Global funding of nanotechnology research, by region (Cientifica 2012).

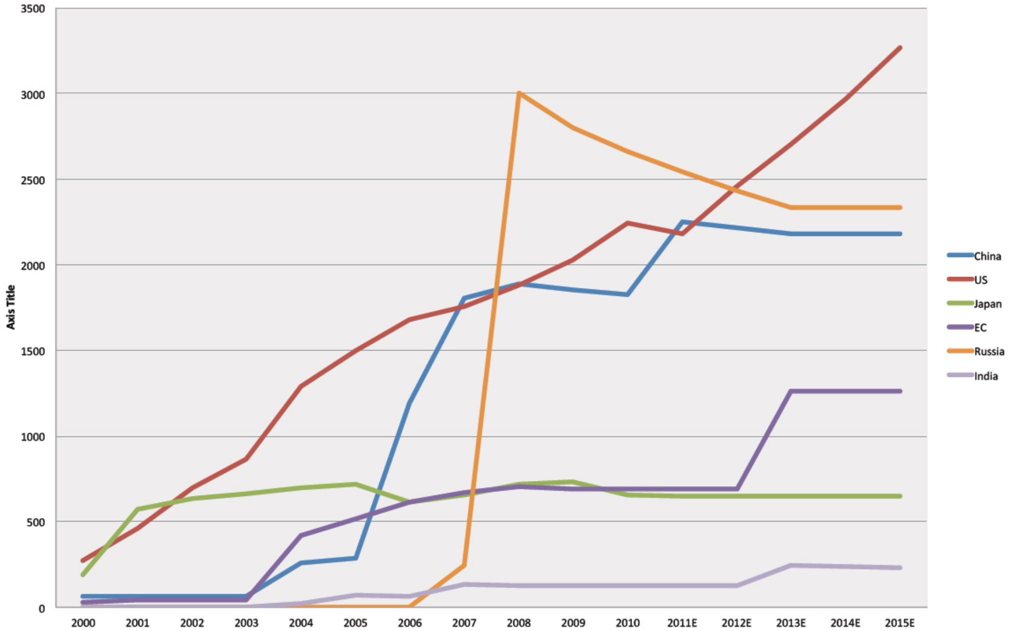

Figure 8.2. PPP-corrected global funding of nanotechnology research (Cientifica 2012).

In the case of nanotechnology exploitation, the ability to commercialize emerging technologies is modified by factoring in R&D funding levels, which puts the United States at the top of the table, closely followed by China, Russia, and Japan. This is supported by contrasting various national nanotechnology fairs or exhibitions, where industrial participation can be low in the case of Taiwan, to significant in the case of the United States and Iran.

The Emtech Exploitation Index (EEI) is a measure of how well a country can exploit its nanotechnology research. There is no guarantee that a big nanotechnology impact will be seen in countries that are good at exploiting emerging technologies. Although this seems to hold true for the United States, Germany, and Japan, others do not score high on both counts even if they are heavy investors in nanotechnology such as Russia and China. Russia and China are taking a calculated but necessary gamble on nanotechnology, in order to keep pace with the United States. Simply outspending the United States is not going to bring fast results. Without the necessary infrastructure, experienced researchers, and scientists to develop emerging technologies, they will need to work twice as hard and spend twice as much if they are to outpace the United States in nanotechnology commercialization in the next decade. The United States has both experience and momentum on its side. For some countries, this problem can be overcome in other ways. Saudi Arabia and other Gulf states can afford to attract the world's best scientific talent by offering extremely generous financial and benefits packages. Table 8.1 gives the EEI for several major countries.

Table 8.1. EmTech Exploitation Index Comparisons

Country	EEI Index
United States	5.00
Germany	4.93
Taiwan	4.90
Japan	4.88
S.Korea	4.60
UK	4.55
China	4.30
EU	4.23
India	3.95
Russia	3.57

At the moment, it is quite clearly a three-horse race between China, Russia, and the United States. Chinese nanotechnology investment is likely to increase substantially over the next decade, as this new world superpower looks to innovative and create sustainable ways to satisfy its growing needs for energy and materials. Rather than creating domestic industries, the Russian approach has a greater focus on taking a stake in a variety of preexisting nanotechnology-related companies and leveraging this to attract manufacturing to Russia via the investment vehicle RusNano Corporation (http://en.rusnano.com/).

Cientifica's Nanotechnology Impact Factor (NIF) Index is a measure of the likely impact of a developing nanotechnology sector on a countries' national economy. This is presented in Table 8.2 for several representative countries.

Table 8.2. Nanotechnology Impact Factor Comparisons

Country	NIF
United States	100
China	89
Russia	83
Germany	30
Japan	29
EU	27
South Korea	25
Taiwan	9
UK	6
India	5

Plenary D-2: From Concept to Job Creation

Ginger Lew

CEO, Three Oaks Consulting

Former Senior Counsel for the White House National Economic Council

During the past 15 years, regional technology-based economic planning has become more broadly used by communities in the United States. It is an evolving practice whereby a consortium of cities, counties, states, businesses, educators, and community leaders rely upon technology-driven economic planning and growth strategies for a region. These regional consortia typically conduct assessments of local industries that generate the "pull" for work force skills, advanced education, and other assets to create high-paying jobs. Businesses are attracted to a regional strategy because they now look for regional resources that can support scale and growth, and because these strategies help create robust partnerships. Hence, the general theme of the NNI regional, state, and local workshop is of considerable relevance.

Several studies and reports by the current Administration and various policy bodies support the importance of technological innovation for U.S. economic growth and competitiveness. For example, a January 2012 report by the National Innovation Advisory Board[25] made the case that Federal investments in research, education, and infrastructure have been critical building blocks for U.S. economic competitiveness and job creation over the last century. A January 2012 report by the National Science Board (NSB)[26] found that the United States lost 28 percent of its high-technology manufacturing jobs over the last decade because of its shrinking lead in science and technology. U.S. technology firms have created jobs overseas, and recently Asia has, for the first time, matched the United States in R&D investments.

[25] http://www.commerce.gov/sites/default/files/documents/2012/january/competes_010511_0.pdf
[26] http://nsf.gov/statistics/seind12/

There are several Administration initiatives to promote innovation, including the Institutes for Manufacturing Innovation, which will develop innovative methods for advanced manufacturing techniques. These institutes will be similar to the Virginia Commonwealth Center for Advanced Manufacturing (http://www.ccam-va.com/), a consortium of large and small companies and leading universities. They are focused on training students and workers for advanced manufacturing careers, and on delivering new production-ready solutions to existing factories. Another interesting example is the Innovation District started in 2007 in Providence, Rhode Island—a collaboration between Brown University, the Rhode Island Chamber of Commerce, and business groups that has regenerated traditional businesses and attracted new ones in an economically stressed urban area.

U.S. educational and professional training enterprises are not where they should be, with the United States in the bottom third of all OECD countries when it comes to science and technology graduates, and with 60% of Americans having a reading ability at or below the 7^{th}-grade level. The President's Jobs Council has recommended that the United States form stronger partnerships among communities, businesses, and educational institutions to address workforce development and the needs of the labor market, and to develop meaningful educational standards so that students earn credits based on competence, not credit hours.

The secret to success is collaboration; a critical element in this that is often lacking is a respected intermediary who can convene, cajole, and push the stakeholders.

CHAPTER 9

Day 2 Breakout Sessions: Roadmapping Café

Introduction

At the end of the second day of the workshop, attendees participated in 90 minutes of moderated "café" discussions on 12 separate topics, each discussion having its own table and moderator/note taker. Each attendee had time to participate in three separate discussions. The discussion topics were intended to be forward-looking, seeking to elicit recommendations for best practices and areas of improvement in the functioning of RSLs and how the Federal Government could aid in these areas. At the recommendation of writing team members, the results of these 12 table discussions have been organized below into five broadly themed topics: commercialization, collaboration, policy, workforce, and support for RSL initiatives. A sixth topic is directly based on the twelfth table discussion that explored the question of whether a national roadmap for RSLs would be useful. These discussions are summarized below.

Commercialization

Commercialization of nanoscale materials and technology was an important focus of the workshop. Because RSLs are typically focused on regional economic development and job creation, many discussions revolved around the resources that RSLs are providing or should provide to help nanotechnology companies grow. RSLs can fill gaps between the resources that the Federal Government, corporations, and states provide. During the workshop, several of the regional initiatives shared best-practice information in this regard, as well as their stumbling blocks and case histories. The café table discussions built upon these topics.

In the realm of developing and commercializing new nanotechnology products, leadership was identified as a critical element, in both the public but especially the private sector. On a broad basis, the observation was made that as a nation working "as a team," the combined talent pool of the United States should be able to lead the world in commercialization of nanoscale products. What is required is not only disruptive technology but similarly disruptive business models. A leadership consortium was identified as a potentially disruptive business model, bringing together the leaders from companies that can imagine and implement a new mode of operation to more effectively commercialize nanotechnology products. Another suggestion was to study and emulate the techniques of successful leaders of technology-focused companies, such as Procter & Gamble, General Electric, and Hewlett-Packard, and to make these more available to SMEs and startups.

The table participants identified several important roles for the Federal Government:

- Expand the STTR/SBIR program to include mentors or "entrepreneurs-in-residence" to aid startup companies to improve their chances for survival. This expansion should be accomplished through partnerships with RSL initiatives.
- Make the nanotechnology resources housed at the Federal facilities and National Labs (laboratories, fabrication facilities, people) more available to SMEs. These resources should be appropriately subsidized in order to make them affordable for early-stage companies. The NNI website listing of available resources and facilities[27] should be maintained and enhanced, including information on contracting with the facilities for services.
- Standardize regulation of nanomaterials. A number of participants voiced concern over regional differences or uncertainty in regulation, which was identified as a major impediment to commercialization. Some states are already implementing their own regulations for nanotechnology, with the possibility arising of an increasingly confusing national regulation landscape. RSLs can be a resource to help their states implement clear, factual EHS regulation that aligns with Federal regulation. One recommendation was that an increased national effort be undertaken to determine exposure-specific regulations for nanoscale materials.
- The NNI should consider creating a dialogue between the Nanotechnology Signature Initiatives and the RSLs in order to align goals and possibly share resources.

Collaboration

Collaboration on a large scale was seen by many table participants as a major element in enabling cutting-edge research and commercialization of nanotechnology. Research enterprises at the Federal, state, and local level should be encouraged to utilize social media (Facebook, Wiki, Linked-In, etc.) to promote collaboration and communication. As discussed in the Commercialization section above, increasing incentives to make national laboratory facilities and services available to private industry is one way to boost collaboration. At the university level, incentives can be effective in creating shared user facilities open to all academic and private researchers. In turn, the increased use of facilities can result in not only additional revenue to the institution but also can provide a natural setting for collaboration and development on intellectual property.

Intellectual property licensing regulation and practice, as it pertains to universities and Federal laboratories, was discussed as a major impediment to collaboration between private industry and academic researchers. Reform of the licensing

[27] http://nano.gov/userfacilities

restrictions to encourage licensing of university IP in the United States was identified as a critical need. It was recognized that this has been a problem for decades, but new ideas should be developed to significantly increase the ease with which companies can collaborate with universities and incentivize all parties.

Many table participants noted that financial incentives for collaboration have been successful at many levels, and should be expanded. Examples include incentives for collaborative research built into competitive grants at the local, state, and national level, and "grand challenge" competitions to encourage collaborative research teams.

Policy

Several of the table conversations made suggestions for national or regional policy enhancements. Recommendations fell into several areas: EHS regulation, support of innovation and entrepreneurship through Federal agencies, the new Federal Advanced Manufacturing Partnership, and STEM education. A summary of the main points in each area are described in this section.

Promote Consistency in Environmental, Health, and Safety Regulation

Many participants voiced the opinion that development of nanomaterials and nanoscale products is critically dependent on a predictable regulatory environment. Consistency in EHS regulations at the Federal, state and local level would enhance commercialization prospects in the United States. State or local (city/county) regulations or guidelines would be too confusing to administer and would inhibit product development and marketing. However, a few states are already enacting regulations related to nanotechnology, and this is creating the possibility of a difficult regulatory landscape nationally for nanotechnology companies.

Some participants noted that regulation of new materials at the nanoscale presents a challenge to Federal regulators, including EPA and FDA. Testing each new material or mixture for potential toxicity for all the new products that are appearing is an impossible burden. Depending on exposure scenarios, nanoscale materials may not be regulated adequately with existing regulations. NNI regulatory agencies should reach out to the RSL initiatives as they develop strategies for regulating new materials and products. Especially important is providing support to startup companies that do not have the staff or resources to track regulatory changes or comply with burdensome reporting and data requirements. Agencies should provide assistance and guidance in a proactive, not punitive, fashion.

Extend Federal Support of Innovation and Entrepreneurship to RSLs

Participants identified several Federal programs as important additions to the innovation and entrepreneurship ecosystem. Examples of successful programs include NSF's Innovation Corps (I-Corps) and Accelerating Innovation Research (AIR) programs and EDA's i6 Grants. These programs demonstrate Federal support of innovation in research and commercialization activities and raise the visibility of innovation across the country. Many participants agreed that the scope and eligibility of these programs should be expanded. For example, it was suggested that the AIR program broaden its eligibility requirements to include nonprofits, e.g., RSLs, not just degree-granting universities.

One general comment in this area was that a study should be done of other countries' national policies to promote innovation and nanotechnology commercialization, to see if there are good ideas that can be translated to the United States.

Link to and Promote Advanced Manufacturing Initiatives

Some participants made a strong case that the National Nanotechnology Initiative and the new Advanced Manufacturing Partnership need to be linked, for the benefit of both programs. The AMP was viewed as a very positive development, and its funding and scope should be expanded. AMP involvement in developing new manufacturing methods for nanoscale materials and technology should be a high priority. Particular areas of interface for the AMP and the NNI could be research in areas such as scale-up methodologies and quality control and quality analysis frameworks for nanomanufacturing.

Participants agreed there is a need to promote manufacturing as a national priority. The United States needs to be the chosen destination for talent and capital focused on manufacturing by maintaining a favorable business environment. Inventors, investors, and entrepreneurs need to find the U.S. market to be the best place to do business, and strong national and regional policies to do so should be developed.

Expand the National Nanotechnology Infrastructure Network

There was strong agreement that the availability of cutting-edge instrumentation and fabrication facilities is critical to the development and commercialization of new materials and technology, especially at the nanoscale. NNIN facilities were pointed to as an excellent resource; however, in addition to NNIN facilities, there are other regional networks such as the ONAMI User Facility Network, which makes university laboratories and expertise accessible to industry. A discussion revolved around expanding funding for NNIN and similar networks, and using Federal and RSL resources collaboratively to connect industry and private research with these resources.

Extend Next-Generation Education Policy beyond STEM

Several table participants argued that education policy has the potential for raising the level of competition in the United States across the board in development and commercialization of nanoscale materials and technologies. One key point made during the discussions, and during other workshop sessions, was the need for nanotechnology RSL members to be active participants in the development of next-generation science standards for K–12 education. In addition to building on STEM education at all levels, a focus on nanoscale science would benefit the RSL initiatives' efforts in the near and long terms.

Beyond formal educational settings, some participants saw a need to improve public understanding of nanotechnology, both in the workplace and in the marketplace. There is currently a negative perception of nanotechnology by some members of the public, often fueled by misinformation. Proactive communication programs are needed to counteract unreliable sources of information.

A few participants stated that there is a need to retain the nanoscience and technology talent developed at U.S. institutions at the PhD level and beyond. A significant proportion of PhD and post-doctoral students in the United States are foreign nationals, who may or may not remain in the United States. Developing nations such as China and India have a high interest in advanced STEM education, which may entice foreign students educated in the United States to return to their home countries, taking their technical and entrepreneurial talent with them. Policies to encourage U.S. nationals to continue STEM education to PhD levels, and national and regional policies encouraging U.S.-educated scientists and engineers to remain in the United States, would enhance the competitive position of U.S. technology companies across the board.

Finally, as a more general comment, some participants recommended that RSLs develop a clear and consistent message for who they are and what they do, and take advantage of opportunities to communicate their ideas and viewpoints to the Federal Government, for example, through public comment mechanisms, or by engaging their Congressional delegations.

Workforce

Workforce issues arose in several of the table discussions. Most participants agreed that a key to workforce development is education, which was thoroughly discussed. At the K–12 level, STEM education is critical, and should be enhanced by additional opportunities for students to engage with mentors in hands-on activities, such as the FIRST Robotics programs,[28] Science Olympiads, and regional/state science fairs. An increased focus on nanoscience and nanotechnology, and engagement by researchers and industries in the field, would build the potential to recruit more students and workers for a future U.S. nanotechnology workforce.

Participants had an extended discussion about actions that could improve U.S. competitiveness in nanotechnology. In the short-term, easing immigration barriers for technically trained people would increase competitiveness for the U.S. nanotechnology sector. In the longer term, it was suggested that the NNI, the Department of Education, and the Department of Labor could jointly work with community colleges on the development and deployment of technical training programs for the nanotechnology workforce. Developing a skilled workforce depends on attracting the right students, not limited to recent high school graduates. Programs at the community college level should reach out to returning veterans, adults looking to start second careers, and workers in industries being

[28] http://www.usfirst.org/roboticsprograms

downsized or moved offshore. These training programs need to be linked to networks of nanotechnology resources such NNIN, Federal and state shared user facilities, or companies that can offer students training and experience on instruments. It was noted that successful instrumentation training starts with virtual or remote instrument operation and proceeds to hands-on training and potentially to internships, which is also a cost-effective strategy. Community and two-year technical colleges should also work more closely with local businesses and industry to determine their technical and staffing needs and to develop joint programs.

Many participants noted that at the undergraduate level, STEM education in nanotechnology is going well. Introduction of additional nanoscale content would be beneficial. The nanotechnology community should build on good models for ongoing education that incorporates nanotechnology, such as the ones at Forsyth Tech (NC), Pennsylvania State University, Dakota Community College (MN), and others. As mentioned above, universities should look beyond their self-identified STEM students. One suggestion was a survey course for first-year students in non-STEM majors.

Several participants expressed the view that the workforce sector composed of PhDs, post-doctoral students, and entrepreneurs needs increased exposure to STEM commercial opportunities. Entrepreneurs should be matched up with PhD researchers to identify and aid commercialization, as is being done successfully by some RSL initiatives. The NSF I-Corps Program was mentioned as a great training tool for technical entrepreneurs. Universities should also recognize and reward entrepreneurial activity by STEM faculty. For students, business plan competitions that involve nanotechnology research students are also a promising mechanism.

Finally, some participants suggested that researchers at Federal laboratories be made available to work with entrepreneurs, industry, and RSLs because they are a great resource.

Support for RSL Initiatives

There was extended discussion by table participants about the role of RSL initiatives, including options for expanding commercialization programs and linking the national Advanced Manufacturing Partnership to the RSL initiatives. Some participants recommended that Federal agencies partner with qualified commercialization gap funds and RSLs, ideally with block grants or matching funds. The benefit of RSL Initiative involvement would be to produce companies that are more likely to commercialize their innovations successfully, to be more credible SBIR candidates, and to be more viable companies. It was also suggested that the RSLs should take advantage of local business, industry, and community resources to provide business mentoring to entrepreneurs from the science or engineering research community.

A significant discussion by table participants was centered on defining the characteristics, roles, and expectations for RSL initiatives. A key recommendation was that documentation be developed of best practices for the RSL initiatives, including a broad definition of an RSL initiative and its roles. Each Initiative should have a mission, goal, and defined plan of action. The NNI should monitor and report on the progress of the RSLs by collecting data in an ongoing fashion and making it available. It was noted that by utilizing such best practices, the RSLs have the ability to deliver disruptive technologies not otherwise supported. The RSL initiatives should also be in a position to advise Federal agencies on coordination of policy, possibly by developing a national community of interest and engaging with Federal entities.

Several participants recommended that NNCO develop an RSL website including contact information and current updates from each initiative. Information sharing between the initiatives should then be encouraged and enabled via web updates and more frequent meetings (including web-based conferences).

Key Elements of an RSL Roadmap

The twelfth café table was devoted to the issue of whether a national roadmap for NNI and RSL collaboration would be a useful exercise, and if so, how it would be created, and who would participate in the process.

Role for RSLs

Regional, state, and local Initiatives have developed across the United States to address geographical priorities for job creation and economic development that fall outside of the role of the Federal Government. States, and in some cases cities, have stepped into this gap to provide new organizations, methods, and expertise to focus efforts on local conditions, that is, the types of jobs, industries, and business models that leverage and extend existing resources.

Because of the influence of local conditions on RSL development, RSLs vary widely in structure, membership, and purpose. These differences make it hard for the Federal Government to define nanotechnology RSLs and to fashion broad mechanisms of support. Several participants at this table recommended identification by attributes, such as state and city involvement or focus on a specific industry sector, or identification by outcomes, such as job creation or number of industries developed.

Considerations

Key elements of a national RSL nanotechnology initiative roadmap that were identified by participants included mechanisms or processes to:

- Establish clear, shared goals or endpoints.
- Collect, evaluate, and share best practices and local elements critical to success.
- Support STEM education and workforce development, including curriculum modules, standards, and accreditation.
- Identify existing regional, state, and local entities that could be brought into the nanotechnology sphere.

- Develop or identify tools that can be used to assist local governments in understanding the importance of supporting and investing in nanotechnology-related RSLs.
- Share some control of Federal funding with local governments or groups in order to bridge the mission-specific focus of Federal agencies.
- Manage conflicts of interest that develop in business models that include research as well as spinoffs, products, and profits.

Breakout session participants noted that their comments were predicated on an underlying assumption that cooperation between the Federal Government and RSLs is necessary and advantageous and that there is a need to establish linkages between them.

Recommendations

In summary, the participants in the RSL roadmap discussions agreed on two main recommendations:

1. Develop an RSL network

There is a need to develop an RSL network to share information and best practices on issues faced by RSLs. These networks should be tailored to the needs of the participating RSLs, and social media tools such as LinkedIn, wikis, and websites should be considered.

2. Provide means for RSLs to communicate

There is a need to create opportunities for RSLs to meet face-to-face or, especially when the economy is challenged, to meet virtually so that RSLs can extend beyond their state and regional barriers.

CHAPTER 10

Recommendations and Next Steps

One of the principal goals of the 2012 NNI RSL workshop in Portland was to gather ideas and recommendations from RSL representatives and other stakeholders about (1) possible actions that could be taken to improve the success of nanotechnology RSLs, and (2) ways the NNI could be more effective in supporting them and improving collaborative activities. Many recommendations were offered during the event by speakers, breakout session participants, and attendees during question-and-answer periods and networking events. This chapter summarizes some of the recommendations most frequently mentioned by workshop participants during the presentations and discussions on May 1 and 2, reflecting the synthesis that was developed at the May 3 writing session. The recommendations are not meant to be exhaustive or authoritative, but they are representative of issues that were repeatedly identified as important by participants during the course of this workshop.

To organize the significant number of recommendations that arose during the workshop, writing session participants[29] developed a taxonomy of six major themes that related to various aspects of RSL activities. Those themes are used in this chapter to organize and present the recommendations of this report. Additionally, the writing team members identified a few "next steps" that could be taken to continue the RSL dialogue beyond the workshop, with an eye toward potentially creating an ongoing RSL community of interest. Those next steps are presented at the end of this chapter.

Recommendations

Commercialization

- Expand the scope of the Federal SBIR/STTR programs to allow funding for "entrepreneurs-in-residence," and allow nonprofits such as RSLs to receive such funding.
- Increase subsidies or reduce costs for small and medium sized nanotechnology businesses to use Federal or state shared-user infrastructure facilities.
- Create a forum to standardize nanoEHS regulation among the states, and help harmonize with Federal regulations, to foster a more uniform regulatory climate

[29] Vince Caprio, Khershed Cooper, Kevin Conley, Ed Cupoli, Tony Green, Charlie Gauss, Geoff Holdridge, Jim Kadtke, Matt Kim, Griff Kundahl, Jim Mason, David Mathews, Skip Rung, and Sally Tinkle.

for U.S. businesses. RSLs can also be a resource for their SMEs to help them understand Federal and state nanoEHS regulations.

- The NNI should support or encourage the creation of an annual "snapshot" of industry-selected, commercially viable innovations that have reached an actionable stage of their development. One mechanism to do this is to have each NNI partner agency encourage their awardees to participate by submitting their commercially viable technologies into the NSTI database.
- Develop mechanisms that provide (global) nanotechnology market analysis that can be made available cheaply to RSLs and the SMEs they support.
- Generally, RSLs should support their businesses and startups by helping with intellectual property development, licensing agreements, access to user facilities, providing seed stage funding in the $10,000–$250,000 range, developing STEM education resources, and also by providing experienced entrepreneurial advice.
- The NNI should consider creating a dialogue between the NNI Signature Initiatives and the RSLs in order to align goals and possibly share resources.
- The NNI should consider doing a study of other countries' innovation and nanotechnology commercialization mechanisms and policies, both good and bad, to see if there are insights that might inform current U.S. activities.

Collaboration

- Generally, increase incentives for universities and research entities to provide shared user facilities and collaborative environments, since these are some of the most effective mechanisms to bring researchers, businesses, and stakeholders together.
- Such financial incentives for collaboration could include provisions for multidisciplinary and multi-team collaboration built into grant solicitations at the Federal and state level, as well as "grand challenge" competitions.
- A disincentive to collaboration for decades has been the difficulties some SMEs and RSLs encounter when attempting to buy or license IP from universities; better mutual understanding and creative new ideas would improve this climate.
- Social networking tools are increasingly effective at facilitating collaborative activities among researchers (especially students), educators, businesses, and other stakeholders. These should be promoted more effectively by RSLs and other organizations promoting commercialization of nanotechnologies.
- RSLs and the NNI should sponsor more RSL-focused workshops and conferences, specifically addressing topics important to their communities and regions.
- RSLs should examine more closely the "institutes-of-collaboration" or "proof of concept centers" models for technology-based economic development as a means of defining their roles in their regions.
- Effective planning, roadmapping, goal-setting, and the development and rigorous tracking of realistic metrics of success can be effective mechanisms to encourage regional collaboration among researchers, businesses, leadership, and stakeholders, and should be utilized by RSLs.

Policy

- NNI Federal regulatory agencies should reach out to RSLs to collaborate on collecting data, informing state and local regulation of nanotechnologies, and providing information to businesses and the public on the regulatory environment and nanoEHS best practices. RSLs can also be effective in helping their states develop factual and effective nanoEHS regulations that align with Federal regulations, and which appropriately leverage existing materials regulatory policies and risk/benefit tradeoff approaches.
- Federal programs that promote innovation and commercialization, such as the NSF I-Corps and EDA i6 programs, should consider ways to take better advantage of what RSLs can do in promoting nanotechnology-based economic development.
- The Administration's new Advanced Manufacturing Partnership is a very positive development, and efforts should be made to link and coordinate AMP, NNI, and RSLs to help commercialize U.S. nanotechnology R&D more effectively.
- Shared user facilities are critical to commercialization of nanotechnology in the United States, and NNIN and other NNI user facilities should be expanded and linked with state and regional shared user facilities, such as the ONAMI User Facility Network.
- Nanotechnology RSLs should take an active role in the development of science standards for K–12 education at the Federal, state, and local levels. Improved nanotechnology elements in STEM curricula would benefit RSL efforts in both the mid- and long terms.
- RSLs should help advocate for immigration policies that allow exceptional U.S.-educated foreign students to remain in the United States and advance nanotechnology commercialization, a practice that has led to increased U.S. citizen jobs in semiconductors and other advanced technology fields.
- RSLs as a community should develop much better arguments for why their expenditures should be considered alongside other important state needs, and also how to make their results more relevant and appealing to the average citizen.
- RSL best practices and policy could be better informed if a number of case studies were developed that analyze specific RSLs in considerable detail, including operational models and actual numbers for financial activities and metrics for economic impact.
- RSLs should provide input on tax policy and financial incentives at the local, state, and possibly Federal levels, and they should substantiate the potential benefits of new incentive mechanisms, such as R&D tax credits for collaboration or angel investment in nanotechnology startups.
- In general, RSLs should develop a clear and consistent message for who they are and what they do, and take advantage of opportunities to communicate their ideas and viewpoints to the Federal Government, for example, through public comment mechanisms, or by engaging their Congressional delegations.

Workforce

- A critical element to develop the future nanotechnology workforce is STEM education at the K–12 and university levels, and RSLs and the NNI should foster nanotechnology-oriented STEM education by helping develop information and curricula, and by promoting nanotechnology more broadly to the public. In particular, programs that provide mentors, hands-on activities, and science fairs and challenges are important to supplement classroom activities. Technical universities and two-year colleges should also partner with local nanotechnology businesses and industry to determine their staffing needs, and perhaps, to develop joint educational programs or leverage resources.
- The NNI, the Department of Labor, the Department of Education, and RSLs should collaborate to develop and deploy nanotechnology STEM curricula to community and technical colleges to help train technician-level workers. The programs should also be linked to resources such as NNIN and other NNI shared user facilities, to provide hands-on experience.
- Aspects of business education and entrepreneurial skills should be incorporated in nanotechnology STEM education at the university and community college levels. Business plan competitions involving STEM undergraduate and graduate students have been a useful mechanism.
- Funding should be available to support researchers from Federal nanotechnology research centers to mentor and support RSLs and their businesses.
- The NNI should continue to enhance its efforts to maintain an extensive, cohesive, certified repository of standardized nanotechnology educational content for educators nationally.[30]

Support for RSL Initiatives

- The use of gap funds by RSLs for commercialization of nanotechnology-enabled products should be expanded, and Federal agencies should determine what mechanisms they have, or could implement, to make matching grants of up to 1:1 available to RSLs for this purpose.
- RSLs should take greater advantage of local business, industry, and community resources to provide business mentoring to entrepreneurs from the nanotechnology research community (because even great technologies don't sell themselves).
- Documentation of best practices for nanotechnology RSL initiatives should be developed, beginning with a definition of an RSL initiative and its possible roles. The NNI should also monitor and report on the progress of the RSL initiatives by regularly collecting data and making it available.
- NNCO should continue to enhance its RSL initiatives website[31] and point to others containing contact information, relevant data, and current updates for each initiative. Information-sharing between the initiatives should be

[30] For example on the NSF and NNI websites (http://www.nsf.gov/discoveries/index.jsp?prio_area=10; http://nano.gov/education-training), which provide a considerable amount of information about nanotechnology education content, for both educators and the general public.
[31] http://nano.gov/initiatives/commercial/state-local

encouraged and enabled via these web updates and via virtual meetings such as webinars.

- A regular public newsletter from the NNI, either RSL-specific or about nanotechnology news in general, could be a valuable resource for RSLs and their stakeholders.
- Information from an RSL-dedicated website should be used to collect relevant funding, business, and commercialization data that could inform the development of relevant metrics for the success of nanotechnology-focused RSLs. This could enable better planning and organize the collection of success stories.

RSL Roadmapping

- Because of the wide variety of RSL operational models and regional distinctions, it is difficult for NNI agencies to fully understand and develop broad mechanisms to support and collaborate with them. A joint roadmapping exercise involving the nanotechnology RSL community could greatly inform future collaborations among all parties.
- A national roadmap for nanotechnology RSLs should take into account what has been learned from past and present initiatives, and incorporate information specific to the locale or region being considered. Information and analysis could include aggregated annual performance data on RSLs, and should include strengths, weaknesses, successes, and failures in order to develop and refine models and a forward-looking collaborative plan.
- A national roadmap for nanotech RSLs should establish clear, shared goals and endpoints; define a plan to develop and disseminate best practices; define mechanisms to develop nanotechnology STEM educational resources; delineate the kinds of regional and state entities and resources that could be engaged; identify tools that could be used to inform and engage state and local governments and stakeholders; and define new ways to leverage funding and resources between the Federal and state governments and the private sector.
- The RSL community should also consider the formation of a nationwide alliance or council to help develop common goals, objectives, resources, and messaging in order to strengthen RSL voices within individual states and nationally.

Next Steps

The workshop writing session participants proposed a few action items that could be taken in the short-to-medium term to facilitate continuing the dialogue about RSLs that developed at the workshop, and to help promote collaboration and information-sharing between RSLs and the NNI:

- RSLs should take steps toward developing a virtual community of interest, for example by organizing conference calls, an email listserv, or social media to facilitate keeping engaged and to help develop future plans.
- NNI agencies should consider having a small follow-on workshop with RSL leadership to discuss in more concrete terms how to move forward on some of the recommendations of this workshop.

- RSLs should consider developing a dedicated website for their community, possibly in collaboration with NNI/NNCO, as a networking resource and repository of information about the RSLs.[32]
- NNCO should improve its online resources for RSLs on the NNI website http://nano.gov, including populating the new Nanotechnology Resource Map[33] on that website with additional information specifically about the RSLs.
- RSL representatives should consider organizing panels or sessions at major nanotechnology conferences that deal specifically with RSL issues.

[32] The National Nanomanufacturing Network will host this website.
[33] http://nanodashboard.nano.gov/nanomaps/map.aspx

Appendix A: Workshop Agenda

Monday, April 30: Pre-Workshop Site Visits and Welcome Reception

8:45 Tours of Intel, FEI, and the "Silicon Forest". Lunch at the historic McMenamins Cornelius Pass Roadhouse. Afternoon tour at Portland State Business Accelerator (nanotech startups) and the Center for Electron Microscopy and Nanofabrication (ONAMI shared user facility), and NWNanoNet™ remote access demo.

6:00 Welcoming Reception; comments by Senator Ron Wyden (D-OR)

Tuesday, May 1

7:30 Registration and Continental Breakfast

8:30 Welcome Address & Overview of the Workshop

Skip Rung, Executive Director of the Oregon Nanoscience and Microtechnologies Institute (ONAMI)

Robert Pohanka, Director of the National Nanotechnology Coordination Office (NNCO)

Comments by Congresswoman Suzanne Bonamici (D-OR)

9:00 Keynote: Overview of the NNI and Related Federal Initiatives

Altaf Carim, White House Office of Science and Technology Policy (OSTP)

Session A: Federal Resources and Initiatives for RSLs

Session Chair: Skip Rung, ONAMI

9:30 Retrospective on NNI RSL Initiatives

Clayton Teague, former NNCO Director

10:00 Coffee and Networking Break

10:30 Nanomanufacturing and the NNI Signature Initiative

Alex Liddle, Group Leader of the Center for Nanoscale Science and Technology (CNST) Nanofabrication Research Group at NIST

11:00 Panel Session: Federal Resources for Initiative Programs

Moderator: Sally Tinkle, NNCO

Panelists: Mike Meador, NASA; Sandra Chapman, National Institutes of Health, National Cancer Institute (NIH/NCI); Chris Cannizzaro, State Department; Khershed Cooper, Department of Defense (DOD); Ben Schrag, National Science Foundation (NSF); and Altaf Carim, OSTP

12:00 Lunch: Keynote: "The Imagination Economy: The Public Sector can be a Partner and a Potent Catalyst to Build a Stronger Economic Future"

Ted Wheeler, Oregon State Treasurer

Session B: Current Landscape of RSLs and their Status

Session Chair: Jim Murday, University of Southern California

1:15 Overview of Current RSL Landscape
Jim Mason, Oklahoma Nanotechnology Initiative

1:45 National Overview of RSLs and Tech-Based Economic Development
Mark Skinner, State Science and Technology Institute (SSTI)

2:15 Panel Session: RSL Representatives Discuss Their Challenges and Successes
Moderator: Vince Caprio, NanoBCA

Panelists: Jim Mason, Oklahoma Nanotechnology Initiative; Griff Kundahl, Center of Innovation for Nanobiotechnology (COIN); Skip Rung, ONAMI; Kevin Conley (Forsyth Tech); Osama Awadelkarim (PSU-NACK); Ed Cupoli, SEMATECH

3:15 Coffee and Networking Break

3:45 Charge to Breakout Sessions
Workshop Co-Chair Jim Kadtke

Breakout Session Topics

1. Resourcing the Commercialization Lifecycle
Co-chairs: Skip Rung and Ben Schrag

2. Fostering the U.S. Nanotechnology Workforce
Co-chairs: Jim Murday and Kevin Conley

3. Reducing Uncertainty in the Marketplace: Regulation, Insurance, and Risk Management
Co-Chairs: Rick Pleus, Charlie Gause

4. Effective Partnering for an Innovation Ecosystem
Griff Kundahl and Mary Jo Waits

5. The Value Proposition of RSL Nanotechnology Initiatives
Co-Chairs: Tony Green, Egils Milsberg

5:15 Report-Out on Breakouts and Synthesis

6:00 Public Comment Period (15 minutes)
Moderator: Sally Tinkle

6:30 Reception

7:00 Banquet; Keynote: “How Innovation Enhances American Competitiveness”
Brian Markwalter, Consumer Electronics Association

Wednesday, May 2

7:30 Continental breakfast

8:30 Welcome back; Overview of Day One
Workshop NNCO Staff Lead Jim Kadtke
Comments by Senator Jeff Merkley (D-OR)

9:00 Keynote: "A Co-Innovation Business Model: Lessons from an Industry Perspective"
Sam Angelos, Hewlett Packard

Session C: RSL Best Practices, Business Models, & Mechanisms for Partnering

Session Chair: Bettye Maddux, CSMC/ ONAMI

9:30 An Industry Perspective: "Partnerships: Driving the Materials Revolution"
Travis Earles, Lockheed Martin

10:00 Coffee and Networking Break

10:30 Best Practices for Innovation in RSLs
Mary Jo Waits, National Governors Association (NGA)

11:00 Panel Session: Forward Looking Problem Solving, Improved Models, & Policy and Legislative Proposals
Moderator: Jeff Morse, University of Massachusetts

Panelists: Deb Newberry, North Dakota Community College; Rick Pleus, Intertox; Matt Laudon, Nano Science and Technology Institute (NSTI); Tony Green, Ben Franklin Technology Partnership; and Ross Kozarsky, Lux Research

12:00 Lunch; Keynote: "Nanotechnology – A Global Perspective"
Don Kania, President and CEO, FEI

Session D: RSLs and Future U.S. Economic Growth: From Concept to Action

Session Chair: Cindy Dahl, VP of Operations at ONAMI

1:15 Global Trends in Nanotechnology
Tim Harper, Cientifica

1:45 Challenges of Job Creation
Ginger Lew, Three Oaks Consulting

2:15 Instructions for Roadmapping Sessions
Skip Rung and Jim Kadtke

2:30 RSL Roadmapping Café

4:00 Report Outs and Synthesis on Roadmapping Café

5:00 Adjourn

6:00 Group Dinner for Day 3 Writing Teams

Thursday, May 3: Writing Team Sessions

Session co-chairs and writing teams are required to attend, but all are invited.
Session leaders: Skip Rung and Jim Kadtke

Charge to writing teams, review of breakout groups' materials by panel chairs and discussion leaders, followed by writing sessions and a working lunch

Appendix B: List of Workshop Participants*

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Appendix C: RSL Resource Links & Presentation Links

Lists of RSL initiatives and some resources for RSLs are available on the NNI website, http://nano.gov/initiatives/commercial/state-local. Many of the speaker and poster Presentation files from the 2012 NNI RSL Workshop are also available on the NNI website at http://nano.gov/node/835, as listed below.

Speaker Presentations

Sam Angelos, Hewlett Packard. *A Co-Innovation Business Model: Lessons from an Industry Perspective*.

Altaf Carim, OSTP. *Overview of the NNI and Related Federal Initiatives*

Tim Harper, Cientifica, Ltd. *Nanotechnology Funding: A Global Perspective*.

Don Kania, FEI. *Nanotechnology: A Global Perspective*.

Ginger Lew, Three Oaks. *From Concept to Job Creation*.

J. Alexander Liddle, CNST/NIST. *Nanomanufacturing and the NNI Signature Initiative*.

Jim Mason, Oklahoma Nano Initiative. *Overview of Current RSL Landscape*.

Robert Pohanka, NNCO. *Workshop Welcome Address*.

E. Clayton Teague. *Retrospective (and Some Prospective) on NNI RSL In*itiatives.

Mary Jo Waits, National Governors Association. *Best Practices for Innovation*

Panel A: *Federal Resources for Initiative Programs*. Moderator: Sally Tinkle, NNCO

Panel B: *RSL Representatives Discuss Their Challenges and Succe*sses. Moderator: Vince Caprio, NanoBCA

Panel C: *RSL Best Practices, Business Models, and Mechanisms for Partnering*. Moderator: Jeff Morse, University of Massachusetts Amherst

Poster Presentations

Hawaii High Tech Development Corporation

Kentucky nanoNET

NanoEx: Pathways to Workforce Success (McREL, BSCS, and Education Northwest)

Arizona Nanotechnology Cluster

ONAMI (Oregon): SNNI (Safer Nanomaterials and Nanomanufacturing Initiative)

ONAMI (Oregon): CSMC (Center for Sustainable Materials Chemistry)

NACK Center: National Center for Nanotechnology Applications and Career Knowledge

Ohio Nano-Network

University of Louisville Micro/Nano Technology Center

USTAR (1 of 2): Utah Nanofab

USTAR (2 of 2): Utah Nanofab (Teams and Centers)

West Virginia University Shared Facilities

Appendix D: List of Acronyms

AMP	Advanced Manufacturing Partnership
ARPA-E	Advanced Research Projects Agency - Energy (DOE)
BFTP	Ben Franklin Technology Partners
CEA	Consumer Electronics Association
CNSE	College of Nanoscale Science and Engineering at NY State University at Albany
CNST	Center for Nanoscale Science and Technology (NIST)
COIN	Center of Innovation for Nanobiotechnology (NC)
DARPA	Defense Advanced Research Projects Agency
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOS	U.S. Department of State
EDA	U.S. Economic Development Administration (DOC)
EHS	environmental, health, and safety
EPA	Environmental Protection Agency
EPSCoR	Experimental Program to Stimulate Competitive Research
ERC	Engineering Research Center (NSF)
FDA	Food and Drug Administration
IP	intellectual property
I/UCRC	Industry/University Cooperative Research Center(s) (NSF)
NCI	National Cancer Institute (NIH)
NGA	National Governors Association
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NISE Net	Nanoscale Informal Science Education Network
NIST	National Institute of Standards and Technology
NNCO	National Nanotechnology Coordination Office
NNI	National Nanotechnology Initiative
NNIN	National Nanotechnology Infrastructure Network (NSF)
NNMI	National Network for Manufacturing Innovation
NSE	nanoscale science and engineering
NSEC	Nanoscale Science and Engineering Center(s) (NSF)
NSF	National Science Foundation
NSI	Nanotechnology Signature Initiative
NSTI	Nano Science and Technology Institute
NTI	Nanotechnology Institute
NSRC	Nanoscale Science Research Center(s) (DOE)
OECD	Organisation for Economic Co-operation and Development
ONAMI	Oregon Nanoscience and Microtechnologies Institute
ONI	Oklahoma Nanotechnology Initiative
OSTP	Office of Science and Technology Policy (Executive Office of the President)
PCA	Program Component Area (NNI)
PPP	public - private partnership
RSL	Regional, state, and local nanotechnology initiative
SBIR/STTR	Small Business Innovation Research and Small Business Technology Transfer programs (at various Federal agencies)
SME	small-/medium-sized enterprise
SSTI	State Science and Technology Institute
STEM	science, technology, engineering, and mathematics
TBED	technology-based economic development
VC	venture capital

National Science and Technology Council; Committee on Technology
Subcommittee on Nanoscale Science, Engineering, and Technology

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