NATIONAL NANOTECHNOLOGY INITIATIVE

SOUTHERN REGIONAL WORKSHOP

Nanotechnology:

From the Laboratory to New Commercial Frontiers

Rice University • McMurtry Auditorium, Duncan Hall • May 23, 2002

NATIONAL NANOTECHNOLOGY COORDINATING OFFICE

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FINAL REPORT

Nanotechnology Workshop:
From the Laboratory
to
New Commercial Frontiers

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A Regional Workshop of the National Nanotechnology Initiative

Organized by the Rice Alliance for Technology and Entrepreneurship, the James A. Baker III Institute for Public Policy and the Center for Nanoscale Science and Technology

Sponsored by the U.S. Department of Commerce, U.S. Department of Energy, Federal Aviation Administration, National Science Foundation, and the National Nanotechnology Coordination Office.

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EXECUTIVE SUMMARY

Rice University hosted a National Nanotechnology Initiative Southern Regional ***"Nanotechnology Workshop: From the Laboratory to New Commercial Frontiers"*** on May 23, 2002. This was the second regional workshop sponsored by the National Nanotechnology Initiative, U.S. Department of Commerce, the Federal Aviation Administration, U.S. Department of Energy, National Science Foundation, and the National Nanotechnology Coordination Office. The first was held at the University of California at Los Angeles in September 2001 and two more are planned for the Midwest and the Northeast.

The Rice University Workshop convened nearly 400 leaders from industry, government, academe and the financial community to consider the future of nanotechnology. In particular, the workshop explored trends, opportunities, and challenges regarding the translation of laboratory research in nanotechnology into commercial products that can benefit society. The Workshop focused on four areas of application or concern: energy/petrochemicals, molecular electronics, medicine/life sciences, and aerospace/materials science. Aspects of human capital needs (workforce education and training) were of interest for all four application areas.

Major points from the meeting:

- *Maintaining U.S. Leadership in Nanotechnology*. There is concern among the science and engineering communities that the U.S. may lose its lead in nanotechnology research. Creation of new knowledge is not exclusive to the U.S. To maintain our lead, it is anticipated that policy makers must consider increasing federal funding two-, three-, or four-fold in physical sciences with a major portion to nanotechnology in the overall science and technology budget. Also, to successfully compete against other countries, policy questions, such as the control of exports of nanotechnology products, must be examined and resolved.
- *Maximizing Nanotechnology's Benefit to Society*. Government policy makers must articulate action steps regarding how to ensure society's maximum benefit from nanotechnology discoveries. A progression exists beginning with basic nanotechnology research, applied research, prototype development, commercial product roll out, and business expansion. The government should enhance its ability to facilitate the transformation of basic research to commercial products. This can be achieved by government leadership as a clearinghouse for information about, for

example: (1) federal, regional, and state, nanotechnology research consortia (partnerships among universities or partnerships among universities and companies), (2) universities with "best practices" regarding nanotechnology research and technology transfer, (3) and innovative programs in K-12 or higher education for training future workers for the nanotechnology industry. Furthermore, the government should review existing programs, such as Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Advanced Technology Program (ATP), and Manufacturing Technology Program (MANTECH), to ensure that they are well suited to support commercialization of nanotechnology discoveries.

- *Interdisciplinary Partnerships on University Campuses*. For nanotechnology to benefit society, universities must form collaborative partnerships among schools of science, engineering, and business. Through such partnerships, business school faculty and students will become educated about nanotechnology's discoveries in electronics, medicine, and materials. As a result, business students will be drawn into the nascent nanotechnology industry. Similarly, it is critical to educate nanotechnology researchers about the process of commercialization. If researchers are familiar with the commercialization process, their effectiveness as collaborators with businesspersons and investors will be enhanced.
- *Human Capital and Workforce Skills*. The human capital demands of the nanotechnology industry will be met in the near term only if training about nanotechnology is delivered to workers currently in other industries. Moreover, the intrigue of nanotechnology provides a new gateway for attracting schoolchildren to learn about science, math, engineering, and technology. To develop the nanotechnology workforce of the future, schoolchildren must learn about nanotechnology during their K-12 years. Furthermore, universities have begun new degree programs (both undergraduate and graduate) that prepare students to function effectively as researchers, innovators, and executives in nanotechnology companies. These programs should be expanded.
- *Ethical Considerations*. What ethics lessons learned from other fields (e.g., biotechnology) can be applied to nanotechnology? The dialogue among university researchers and companies must intensify regarding potential health and toxicological issues that arise as nanotechnology discoveries advance. University programs training nanotechnologists should require treatment of the ethical challenges of nanotechnology as well as ethical lessons learned from other fields.
- *Balanced Policies Regarding Security Versus the Need for Open Access to Research Findings*. The research enterprise is founded on open exchange of research data and

results. This is mandatory for the "self correcting" nature of scientific research. Yet, in today's heightened security environment, the government must have well-conceived policies regarding what information is deemed "sensitive" and what is "classified." As needed, restrictions must be maintained concerning which technologies are subject to export control and to what information foreign scholars and students are given access.

- *Sector-Specific Applications of Nanotechnology*. There is great potential to solve many of the world's problems through nanotechnology. Several areas of work merit additional government support for basic research such as:
  - Energy: A world without adequate oil and gas will require new technology and many of the most promising "new energy" solutions will come from nanotechnology.
  - Medicine: Interdisciplinary research in nanotechnology/biotechnology will yield dramatic benefits to patients in terms of new pharmaceuticals and medical devices.
  - Molecular electronics: Commercialization opportunities exist in the mid- to far-term. Computation and telecommunications will be heavily impacted by nanotechnology innovations.
  - Aerospace: Extreme environments demand revolutionary materials performance. Expanded nanotechnology research can provide these solutions. This aerospace industry will continue to be dominated by high performance and reliability, although reduced cost is also a necessary target for research and development in this arena.
  - Materials: Because it underlies most areas of nanotechnology, materials research must be expanded, especially in work that involves consideration of both the small size and design of new devices.

The Southern Regional NNI Workshop at Rice succeeded in achieving three goals: (1) it increased awareness by personal contact, by webcast, and by press coverage, (2) it increased the commercialization potential for nanotechnology by exposing the hype and focusing on realistic timelines for commercialization, and (3) it provided feedback to the NNI through direct observation as well as through reporting in multiple media. Benefits from the Southern Regional NNI Workshop are already being realized through further meetings in the Southern U.S. focused on nanotechnology in energy (May 2003), aerospace (Jan 2003), and medicine (several workshop-format meetings are being held in Texas in 2002 and 2003).

WORKSHOP PURPOSE

The purposes of the Regional NNI Workshop were to:

a) Increase awareness of the NNI and nanotechnology throughout the U.S.

b) Accelerate commercialization of nanoscience and nanoengineering.

c) Provide feedback to NNI about needs, new directions and initiatives, especially for commercialization.

WORKSHOP CHARTER

Nanoscale science and technology spans the traditional scientific and engineering disciplines and arises from the growing confluence of knowledge and tools that permit the molecular-level observation, manipulation, and assembly of biological and inorganic materials. The applications of this knowledge will reach broadly: molecular electronics will provide new technologies for computing; efficient energy processes for fabricating net-shape devices and coatings; multi-functional materials internationally designed and self-assembled; new technologies for national defense; and diagnosis and treatment of disease at the molecular scale.

Both large and small companies are investing in the revolution that is underway at our universities. The Federal Government's multi-agency National Nanotechnology Initiative (NNI) will provide more than $700 million in FY03 to support research, and especially favors new collaborations between universities and industry as well as strong linkages to national laboratories. The NNI released its first annual report in June 2002: National Nanotechnology Initiative: The Initiative and its Implementation Plan (FY 2003) NSTC/NSET Report, June 2002 (http://www.nano.gov/nsetrpts.htm). A revised version of this report is forthcoming.

States such as California and New York have invested directly in their public universities to establish nanotechnology centers recognizing the need to build local knowledge in this area and to supply the next generation of scientists and engineers, who will create and develop nanoapplications. Many other states are similarly considering new initiatives, and other non-profit and for-profit organizations are forming partnerships and alliances to participate in this revolution. The barriers to commercialization of nanoscience discoveries are formidable, however. The Southern Regional NNI Workshop at Rice University identified a number of important challenges facing the burgeoning nanotechnology industry.

The Workshop brought together leaders from industry, government, academia and the financial community to explore their views on the future of nanotechnology. The workshop was planned as the second of four in 2001-2002 in various regions of the country. The first workshop, for the Western region, was "Nanotechnology: Opportunity and Challenge for Industry," held September 10, 2001 at the University of California, Los Angeles. The workshop held at Rice University drew attendees from the Southern region of the US predominantly and focused on the importance of nanotechnology to four areas of application or concern: energy/petrochemicals, molecular electronics, medicine/life sciences, and aerospace/materials science.

In each of the areas of application, the workshop addressed questions such as: (1) What are the major technical challenges in nanotechnology? (2) How will society benefit from new discoveries emerging from nanotechnology? (3) What scientific opportunities or trends in nanotechnology have not yet been fully recognized by industry? (4) What are the major obstacles that prevent the investment in and application of new nanotechnology; e.g. in the financial, regulatory, or policy arenas? (5) How will the nation meet the demand for human capital (e.g., workforce education and training) of the emerging nanotechnology industry?

The deliberations and recommendations of the workshop were recorded and provided to attendees and the Federal sponsors. Combined with the recommendations of the other regional meetings, the workshop informed the programmatic and policy discussions that will affect future decisions with respect to nanotechnology.

PROGRAM HIGHLIGHTS

Major points that emerged from the plenary sessions were:

- Professor Neal Lane indicated, “Every nation of the world is looking at nanotechnology as the future technology that will drive their competitive position in the world economy. The U.S. cannot afford to let this one slip away!” He argued that coordinated efforts such as NNI require significant growth in funding for research in the physical and life sciences, outside of biomedical research, and in engineering. These efforts must have ambitious plans and budgets, from the most fundamental research, to technological development, to commercialization as well as plans to develop a skilled workforce to accomplish all this. “Our elected representatives in Washington need to hear from us and our partners in the private sector.”

- The Honorable Phillip Bond, Undersecretary of Commerce for Technology, gave an eloquent and inspiring address, promising to bring his personal enthusiasm for nanotechnology to bolster the U.S. government culture into more support for nanotechnology. His personal advocacy takes three forms: Passion – to instill excitement into Americans about nanotechnology, because it is a key to America’s and the world’s future; Position – to make sure that nanotechnologists’ work is understood in Washington; Politics – to seize the moment wherein we have incredible bipartisan support for nanotechnology. His remarks encouraged everyone to not be seduced by the hype, to work for “more steak, less sizzle,” and to focus on the hope, where sustained investment will lead to real economic growth. Finally, because the field is in the early stages of advancement, we must study the social, ethical and moral issues raised by nanotechnology now, not after the commercial genie is out of the bottle.

- Professor Rick Smalley painted a picture of why nanotechnology is so interesting and attractive to people today. Much of the fascination arises from the public’s feeling that much of nature’s laws are known and there is not much left to find out in science. Nanotechnology excites people by revealing a new world that is yet to be discovered in science and engineering. His broad definition of nanotechnology, “the art and science of building stuff that does stuff at the nanometer scale,” can help excite children to engage in studying science, mathematics, and engineering for the ultimate benefit of humanity. Nanotechnology involves both physical sciences – the dry side, and biological sciences – the wet side, and research at the interfaces between the two will be the source of new revolutions, which will drive the creation of new intellectual property and wealth generation through new companies in medical applications. Viewing the molecular biology revolution of the past several decades as the "nanoization" of biology, we are now entering the era of "nanoization" of the physical sciences as well.

- Dr. Mike Roco, National Nanotechnology Initiative, National Science Foundation. The regional alliances were conceived two years ago to encourage cooperation and increase efficiency among business, government and academic nanotechnology practitioners. A review of the history, structure and size of the NNI was followed by the vision and strategy of the government's investment in nanotechnology. Issues of workforce requirements, societal impact, commercialization and manufacturing, and funding levels are very important for the NNI in the next several years. Other countries are cloning the NNI plan for increasing their nanotechnology investments, and although the US still has the current lead in innovation, maintaining that lead will be challenging. The NNI was formed as a vision of integrating broad areas of education, society, technology, economics, and strategic applications into a unified program, which must remain committed to a long-term vision in order to succeed.

- Dr. Malcolm Gillis, President of Rice University (Luncheon speaker). The 20th Century was very good for industry, with a twenty-fold growth in inflation-adjusted GNP. If 21st Century growth rates are going to match or exceed the last century, new technology must arise and grow. Rice University has played a major role in the creation of nanotechnology, starting from the discovery of the C60 molecule in 1985 by Rick Smalley and Bob Curl. Rice's Center for Nanoscale Science and Technology (CNST) was created to form a major center of "leading edge" nanoscale science and engineering. Only recently has the business side on nanotechnology started to move beyond the "bleeding edge" of research. The prospects are great that nanotechnology will be the driving force for industrial growth across major sectors of the economy.

TOPICAL SESSIONS

SESSION I: ENERGY/PETROCHEMICALS

Altaf Carim, Department of Energy, Office of Basic Energy Sciences

- Dr. Carim overviewed a wide scope of activities in nanotechnology in the Department of Energy (DoE), including applications in fossil energy, energy efficiency, renewable energy, and nuclear energy, such as catalysts, magnetic materials, storage materials, and self-assembled materials. Perhaps the largest impact for nanotechnology advancements will come in the areas of energy generation and utilization. The DoE is encouraging interactions with private industry through funding notices, SBIR/STTR and unsolicited proposal announcements. DoE is investing heavily in new nanotechnology research and user facilities at five of the National Labs, which provide experimental capabilities beyond what is normally available at individual companies or universities.

Dr. Terry Michalski, Sandia National Laboratory

- Nanomaterials will have broad energy implications, but considerable challenges exist regarding the integration of basic research and commercialization integration. The pathways from exploration through discovery to design and fabrication parallel the integration across the boundaries of universities, government labs and industry. Significant needs exist in manufacturing and in performance and stability of the nanostructured products. Successful integration can give, for example, lighting efficiency improvements via nanotechnology which will pay dividends in pollution reduction and reduction of energy usage.

Dr. John Stringer, Electric Power Research Institute

- Electric power is essential today, and consumers demand absolute availability and reliability. A priority for the world is access to adequate energy to provide an acceptable standard of living. The US electric power grid is a single integrated machine and it encompasses a scale from nano- to tera-technology. Transformational technologies such as high temperature superconductivity have not transformed society quickly, and require sustained enthusiasm and funding. Catalysis research is critical for dealing with CO2, including nanotechnology approaches to transform, pump, and store CO2. Quantum wells allow the separation of electrical conductivity from thermal conductivity to enable thermoelectric approaches to efficiency increases.

Dr. Chris Christenson, Dow Chemical Co.

- Large-scale chemical manufacturing requires materials that cost one dollar per pound, in quantities of billions of pounds. To impact the world, nanomaterials must be scaled to these large quantities. Specialty materials in low volumes must deliver properties at the right price, and nanotechnology must be able to provide combinations of sometimes contradictory properties that can't be done in conventional ways, such as stiffness and strength, or high and low temperature performance. The chemicals industry needs low cost starting materials, materials with good rheological properties, and architectures in materials that will allow self-assembly.

Dr. Lewis Norman, Halliburton

- The industry of energy is driven not by good science, but by the economic realities of how to make money. In our grandchildren's lifetime, fossil fuels will be a dinosaur, but for the next 50 years, fossil fuels will continue to drive the industry. But the US's oil and gas reserves will last for only 10 years. With global consumption of fossil fuels increasing, we either have to find and produce more fuels, based on new technical discoveries or develop alternatives to oil and gas. Nanotechnology opportunities abound in fossil fuel exploration, drilling, recovery, transportation, transformation, CO2 management, and process efficiency. For an oil and gas industry of more than $2 billion per day of revenue, R&D expenditures total $4.5B per year, and private industry contributes only $3B, for a rate of 0.15% of revenue. That is not enough to address our fuel needs. The industry needs nanotechnology, but doesn't yet know it.

SESSION II: MOLECULAR ELECTRONICS

Dr. Brosl Hosslacher, Los Alamos National Laboratory

- From its beginnings in molecular self-assembly and development of atomic scale measurement tools in the past decade, ideas for diodes, switches, and memory have rapidly emerged, with many more molecular systems emerging now. It is clear that there are, in fact, a vast number of molecular systems possible. Molecular electronics has emerged with very little federal funding, primarily from DARPA, but in spite of that, many new companies have formed. Experiment is racing ahead of theory, and there is little funding for computing the electronic properties of these systems. The Holy Grail of the field is now memory, and the limit of infinite memory at near zero cost (attributed to Bill Joy) appears to be doable. Current approaches at the atomic scale or hybrids at the mesoscale have hard problems to solve in processing, in communicating between scales, and in integrating with silicon lithography. Killer applications have not emerged, but the field is itself a killer platform. The future may lie in bioelectronics, with approaches that take advantage of Nature's ability to self-assemble perfectly. Using proteins as molecular holders for switches and diodes, viruses are modified to accept the proteins, which then self-assemble onto silicon substrates into two and three-dimensional circuits, that will have incredible density and will be inexpensive.

Dr. James Tour, Rice University

- Analogous to silicon as a replacement for vacuum tubes 50 years ago, molecular electronics faces the same perspective issue as a replacement for silicon – we cannot foresee the scope of the replacement in terms of the many applications that we cannot imagine yet. Molecular approaches are very much different from silicon, in terms of band structure, of size (a million times smaller), of connectivity issues, and especially of fabrication approaches. Molecular electronics is a platform technology, based primarily on bottom-up fabrication ideas. Recent work on functionalizing carbon nanotubes is encouraging in the area of controllable molecular wires (with spin-offs in composite materials.) Self-assembly of molecules for computing devices (non-volatile memory) using post-fabrication programming offers the potential to escape the requirements of lithography, although they are still far from commercialization. Ultimately the field offers a future of "electronics everywhere," with computing and processing power to be found in materials as easily applied as paint. In the meantime, baby steps including molecular electronics embedded in connectors and memories, perhaps as hybrids.

Dr. Herbert Goronkin, Motorola

- Let's add reality to hype and hope, plus intoxication and sobriety. Silicon is near the end of possible improvements, and nanotechnology offers the way forward from silicon. Next generation manufacturing will be in bottom-up processes, and many risks will emerge. The approach being taken in industry now is to explore basic physics, learn how to synthesize molecules, develop a molecular toolbox, and understand how to build molecular circuits. Commercialization, starting from proof of concept, will perhaps require ten years to achieve, following the history of previous electronic systems, and will require more extensive focus on architectures and sustained funding.

Daniel Leff, Sevin Rosen Funds

- For nanoelectronics, industry is being driven by prospects of performance improvements and cost reduction, in order to move beyond silicon's limits. Global competition will be fierce, especially from Japan, where nanotechnology is predicted to be the lynchpin of their future economy. Near term applications are expected to be in flat-panel displays (2003,) sensors in 2004-5, passive optical components and switches in 2005-6, laser and photonic devices in 2006-7, memory by 2010 and logic devices in 2015. Nanohype has raised expectations unrealistically, but reality dictates longer times to see return on investment, probably 7 years or so. Achieving these returns will require a focus on product development. Attractive companies have strong intellectual property portfolios, world-class research teams (especially associations with leading universities), high-value business models, and balanced technical and business teams. Future technical challenges include quality, reproducibility and scalability of devices and materials, rapid, cost-effective assembly methods, and development of novel architectures for computing and other devices. Business challenges include demand for short time-to-market product applications, high value-added business models, and the willingness of investors to fund enabling technology companies.

SESSION III: MEDICINE/ LIFE SCIENCES

Robert Ulrich, Vanguard Venture Partners

- The total investment in nanotechnology business in 2002 is expected to be about $1 billion as estimated by the Nanobusiness Alliance, of which 20% is from the venture capital community. This is comparable to the semiconductor industry at present. To prevent a nanotechnology repeat of the telecommunications industry disasters of recent years, the investment world must take a somewhat more conservative approach. The indicators at present look good for nanotechnology. In biomedicine, analytical, diagnostic, therapeutic, and identification areas are all ripe for high nanotechnology impact. Challenges for the future include understanding of the paradigm shift represented by nanotechnology, matching the market to the technology, clinical adoption issues, and regulatory issues, including educating the regulators about nanotechnology.

Dr. Ed Monachino, National Cancer Institute

- The goal of cancer medicine is to detect cancer much earlier than at present, and find effective cures upon diagnosis. Looking for big payoffs in improved patient benefits, the NCI initiatives in nanotechnology include mechanical and biological sensors, diagnostics including molecular aspects and contrast enhancement, and integrated operations – non-intrusive detection-to-treatment in one visit. The hope is for nanotechnology to offer solutions that render obsolete current therapies. Funding is by function rather than by agency in the NIH. There appears to be much overlap of research in sensors across all government agencies, and there may be efficiencies to be gained by better coordination. NIH funding is heavily weighted toward universities, and little goes to industry. The NIH is stressing tech transfer in its grants, to encourage early recognition of business opportunities by the researchers. Multidisciplinary work is critical to this area, and should be strengthened by developing interdisciplinary centers and educational programs.

Dr. Richard Gibbs, Baylor College of Medicine

- The human genome sequencing project began 10 years ago with preliminary research in biology, hoping that some invention would lead to a way to reduce the cost of identifying each of the 3 billion base pairs in the genome. That did not happen, so brute force methods were used to automate the processes of sequence reactions – batch wet chemistry, flow capillary electrophoresis systems, and computational approaches. The billion dollar investment paid off, albeit through incremental improvements. In order to sequence other organisms, and especially to sequence individual persons, a revolution is still needed, in order to speed up the process and to enable new genetic understanding. Nanotechnology is the route to that revolution.

Dr. Morteza Naghavi, Texas Heart Institute of the University of Texas at Houston, Texas Medical Center.

- Heart disease is the largest killer in western nations, greater than the next seven diseases together (550,000 in the US each year!) The discovery of vulnerable plaque as the underlying cause of most heart attacks has focused attention on the detection of inflamed areas of deposit buildup in the heart and neck arteries. Nanotechnology offers potential new mechanisms for contrast enhancement in imaging techniques such as MRI and ultrasound, including nanoparticles such as nanocrystals and nanotubes. Research could provide entirely new diagnostic methods, and ultimately new treatment methods, provided that we bridge the gaps in technology between medicine and nanoscience and nanoengineering.

Dr. Michael Rosenblum, University of Texas M.D. Anderson Cancer Center

- The medical community is separated from the nanotechnology community by divergent institutional interests (some totally focused on cancer) and approach (some totally engaged in wet, or biological methods). Cancer treatment has moved strongly toward targeted therapeutics, which use antibodies or other agents to find specific target cancer cells. They are then destroyed by various means, such as attached radioactive elements, drugs and toxins. Nanomaterials, especially fullerenes in collaboration with Rice University, offer new approaches to target cancer cells without entry into non-target sites, and potentially even performing multiple functions. These are beyond smart drugs, and perhaps could be called brilliant drugs.

Mary Bass, Spencer Stuart

- Steve Jurvetson (well-known Venture Capitalist) said, “Human capital is the single most limiting factor in the context of building successful nanotech companies.” To attract talent to new nanotechnology businesses, the business must be aware of the availability of talent, the timing required, and the quality of talent relevant to the technology. There is limited availability in any emerging technology, and so the hunt for talent in business leadership entails risk. Business leaders must be found who have an appetite for risk, tempered by reality.

SESSION IV: AEROSPACE/MATERIALS SCIENCE

Dr. Ken Cox, NASA Johnson Space Center

- Nanotechnology is the ultimate frontier of the small, and space is the ultimate frontier of the large. Commonality can be found throughout the great span from cellular to stellar. Interdisciplinary technical challenges and opportunities abound. Market-driven strategies can be derived for the friendly environment of earth, where there are commercial markets of high volume, or for the semi-hostile environment of aeronautical applications, where the markets are for the government or industry. The ultimate challenge is for hostile environments, where government and commercial markets have only small markets, especially in space or deep in the ocean. Issues in nanotechnology for aerospace include innovation of new and modified materials, early applications to demonstrate possibilities and capabilities, manufacturing and affordability, reducing the cost of air or space flight, maintaining industrial profitability, achieving capability improvements, and determining where the significant barriers lie. Human capital in the next decade is a big issue, with changing demographics and continued challenges to interest children in science, math, engineering and technology.

Dr. Barbara Wilson, Air Force Research Laboratory

- The U.S. Air Force must look top-down at critical capabilities and bottom-up at the emerging possibilities in nanotechnology in order to focus its resources in R&D. AFRL is concentrating on nanostructured devices, nanoengineered materials, and in nanoenergetics, along with basic research in nanoscience, especially computational nanoscience. Much of this is driven by improved performance for better or revolutionary capabilities, and for size, weight and cost reduction. Nanotechnology overlaps with biotechnology in AFRL, where biomaterials (the largest area), biocomputing, bioneutralization, biosensors, and cellular dynamics and engineering are of significant interest. Order of magnitude increases are the objectives for investing government money in long-range research and development.

Dr. Chester Kennedy, Lockheed Martin Company

- Despite the enthusiasm in this conference, there is a real danger of the U.S. losing the “nanotechnology race,” if we only maintain our current pace. Other countries will find ways to leverage expertise in nanotechnology to our detriment. The defense and aerospace industries must apply nanotechnology with caution, since any failure to meet the mission 100% puts human life and even our way of life in jeopardy. Hence, there will always be a lag in implementing new technology. Placing nanotechnologies in extreme environments reveals new shortcomings and problems, which will require new scientific research to fully understand. Industry has lost much of its capability to do that research internally, so new partnerships are required.

Dr. John Belk, Boeing Company

- The aerospace industry makes hundreds (at most) of vehicles per year, versus commercial transportation industry where thousands or millions of systems are produced annually. The aerospace industry is now only three large companies in the U.S. The environments are often extreme, and human safety is paramount, but at a cost which won’t break the taxpayer’s pocketbook or bankrupt the company. There are few biologists in aerospace, so collaborations are necessary. Time to market insertion is slow, especially due to regulatory issues. Certification requirements dictate standards, which are needed for nanomaterials and devices – NIST expertise is essential for nanotechnology. Military applications bring along export control, which must change if business in the US is to maintain an international lead in nanotechnology.

Dr. Bob Gower, Carbon Nanotechnologies, Inc.

- Single walled nanotubes (SWNT) may present solutions to many of the requirements stated in the conference. The need is for larger amounts of material to be made available to researchers and developers, in order for the markets to develop. CNI expects to put a manufacturing plant on line in 2005 as the market develops. Unique properties of SWNTs may include electrical and thermal conductivity, as well as high strength. Surface modifications can address issues of dispersability and multifunctionality, enabling their use in biological systems or in aerospace composites.

BREAKOUT SESSIONS

ENERGY / PETROCHEMICALS

The energy industry is the largest in the world, dwarfing the second largest industry (defense,) but the support from the energy industry for research and development is the smallest fraction of all major industries (0.15%). The energy industry has a great deal of capital equipment, and has become a commodity business, producing a narrow profit margin. For-profit companies owe the value of money to their stockholders first, and have a very short-term view of profits and investment. That perspective is not likely to change soon. It is appropriate for the Federal government to support pre-competitive research which is in the best interests of our country and our citizens. Development of advanced, proprietary technology, except for the few mission agencies in the Federal government, occurs in the industrial base. The value of the NNI is in establishing a substantial technology base through large amounts of funded research, and then laying on the requirement for development to occur mostly in the corporate world. The industry has a vested interest in both research and development, however, so that they can make wise investments in technology to ensure their future profits and can understand the technical problems well enough to prevent failures (sometimes catastrophic!) In the chemical industry, the very successful companies balance their short, mid and long term research and development to maintain a pipeline of new technology which ensured survival for the long term. They seldom rely on government funding for their R&D, except for a few high-risk Advanced Technology Programs (ATP) which are co-funded. Should the energy industry pursue nanotechnology? To maintain the world's leadership in energy technology, and to pursue energy independence, the answer is clearly, yes. They will not pursuit nanotechnology, until and unless they receive a short-term benefit, such as a tax credit, from pursuing a long-term strategy and/or they are mandated to do it by Federal law.

Small nano companies can partner with the DOE's national labs (and in fact, any national laboratory) through cooperative R&D agreements (CRADAs) and through SBIR/STTR programs, and now government employees are strongly encouraged to promote and participate in technology transfer activities, including starting new companies while in a leave status. The DOE labs are also building new nano centers to support nano science and engineering by making available new major equipment, as they have done for years with synchrotron sources, for example.

The hype of carbon nanotubes being a great new medium for storing hydrogen has not been verified yet, but the materials reported to date are not the best possible nanotubes to evaluate, so we await further evaluation of their potential as a new energy storage medium. Nanomaterials are of great interest now because they offer tune-ability, or new properties that were unexpected when pursuing research to find a material to solve an insoluble problem. There are few false claims about performance in the ongoing nano-hype, but there are many optimistic claims about potential. Probably cost-reduction will be a major selling point for nanotechnology, rather than small deltas in the performance.

MOLECULAR ELECTRONICS

Many molecular computing concepts will be years away from commercialization, but venture capitalists (at least early stage VCs) who understand the technology and the time horizon well, can invest in a start-up company modestly, help structure the company and develop an appropriate business model to grow the company slowly. Nanotechnology can learn from the biotech companies, many of which began this way in the past two decades. Start-ups, who normally need to focus their efforts to succeed, should consider partnering with larger companies with a specific need for the technology niche owned by the start-up, for example partnering on interconnects in addition to working on molecular memory. Molecular memory may have a 7-10+ year horizon, although the progress may result in a processor concept more rapidly. Start-ups who focus on a specific application, such as a molecular-based detector, can potentially become a market-leader, whereas the larger companies are more likely to be the owners of the platform technologies such as high density, low power nonvolatile RAM, if they maintain their active world-class research groups working on these problems. The large companies need to continue their research programs in molecular electronics in order to build intellectual property for their future needs in memory and processing, and to be able to take advantage of new discoveries elsewhere.

For the NNI to energize the industry, there is a need for nanotech meetings which bring the brilliant ideas together with the “killer apps”, to take us out of the rut of meetings with scientists talking about great science and venture capitalists talking about the need for good business models. The connection of great ideas to great needs is missing today. Also missing are presentations from nanotech start-ups with real numbers to explain their business models and to give good market projections (if they could be persuaded to present them!) Since some $350 M has been invested in nano startups over the past three years, there are some good business models which could be presented where the real applications have connected with the great nano ideas, such as sensors in the petrochemical industry and nanotubes in the display industry.

MEDICINE/LIFE SCIENCES

A challenge for both nanoelectronics and nanobiology is the achievement of directed self-assembly. For nanoelectronics, silicon in a wafer comes from the self-assembly of growing a crystal, which is now top-down manufactured into a device or a system, as opposed to the goal of making semiconductors self-assemble into a functional circuit. Similarly in nanobiotechnology, instead of growing a tree using nature's self-assembly processes and then manufacturing a table by top-down processes involving lumber, our goal might be to grow that tree directly into a table through directed self-assembly. An issue immediately arises that as we succeed in directing nature to produce new smart self-assembling materials (such as drugs,) we must be cautious in ensuring that they will not adversely affect either humans or the environment. The three governmental agencies responsible for this aspect of the NNI are the NIH, the EPA, and the NSF, and the FDA has recently joined the NNI to contribute to this activity in social/ethical/policy issues in nanotechnology. The treatment of nanotechnology by the regulatory agencies should, in fact, be no different than for any other technologies. The major issue is that little funding is available to perform the essential toxicology studies on nanomaterials, which will be expensive and must involve nano scientists and engineers from the outset. At present there are NO funded programs, leaving the industry vulnerable to at best criticism from the public and at worst, lawsuits to prevent the further development of technology until safety is "proven." Other issues in the social arena include the economic implications of displacement of current technology centers by new ones arising from nanoindustry investment. One goal for NNI should be to prevent cold water from being poured on the nanotech revolution through misguided regulation. We must learn from the biotech industry to be absolutely careful as we develop nano drugs and therapies, and to develop not only implementation but also handling guidelines, especially for nano workers.

The very nature of nanobiotechnology is interdisciplinary research and development, which raises the question of how we should attract as well as prepare young people to enter the field. The languages of biotechnology, especially medical biotech, and physical nanotechnology are highly specialized, so particular effort is required to bridge the gap to bring about collaboration or multidisciplinary education and training. Enabling young people to see the excitement in either field is essential to attracting them into the rigorous education program needed for both fields—NNI can and should play a larger role here. NIH wishes to want to fund interdisciplinary programs in nano and bio, and they encourage submission of interdisciplinary proposals, with the recommendation to contact higher level managers to find the appropriate program manager. To encourage young people to study science and engineering, we should build a cultural story about how nanotechnology will be the hot area for the ‘00s and ‘10s, where people with quick minds who are willing to work will be able to get rich and retire early! The NSF centers could and should do more to educate people generally in their regions. But with only 6 or 8 nano centers, that will be hard, so perhaps the NNI and NSF should attempt to place a nanocenter in every state, or to work with the Department of Education to put a nano education center in every state. We should emulate television ads and videos and games to get the message out to people everywhere about nanotechnology specifically, and science and engineering and mathematics generally.

AEROSPACE/MATERIALS SCIENCE

Nanotechnology in aerospace applications has the potential to not only improve performance through new architectures in materials and devices but also through duplication of functions, both of which may offer improved reliability. Reliability is vital in military applications as well as in space operations, where systems need to function for years without maintenance. Much nanotechnology research now focuses on physical aspects, such as making many small units that are inexpensive and work together, perhaps without direct human control (uninhabited). But increasing attention is drawn to aspects of communication, command and control, and information handling from distributed systems. Nano and micro technology offer options for remote and less invasive functions, whether in military or space or even in medical functions. Efficiency improvements in explosive and propellant materials through nanomaterials technology can offer factors of ten improvement due to higher surface areas for oxidation, which will offer civilian as well as military advantages. Improved efficiency for detection of hazardous materials, especially at a distance, is important for research in homeland security as well as in ordinary accident response. Another important area for nanotechnology research to benefit civil defense is in improved reliability of communications, including cellular telephones, but also in extending communication to all people everywhere, outside of the telephone systems. Nanotechnology may make the solutions to these problems less expensive than the brute force ideas now being examined.

An organizational and policy barrier to solving real problems today is the difficulty for governmental agencies to work closely with civilian organizations, due to barriers of sharing information, of cooperating in research and of intellectual property issues. For a multidisciplinary initiative like NNI, these barriers create stovepipes of operation that inhibit progress in technology development and lead to needless duplication of effort and increased costs. There is an apparent real need for changing government regulations to open up the field more, and to allow more communication in the precompetitive environment. Removing restrictions of the types of government money and how they can be applied to nanotechnology research and development would enable more mission or goal oriented activities to move faster with less wasteful administration costs. There also is a need for a clearinghouse of information about nanotechnology, about government programs, about human resources, even possibly about market research for broad applications. If NNI had more autonomy, it could provide such a clearinghouse across all the usual governmental boundaries. For example, in materials research, the oil and gas exploration industry needs better materials for sub-sea environments, but doesn't know where the research in new nano-materials is occurring, relevant to their needs.

Nanotechnology is advancing rapidly in markets for improved products, which offer incremental improvements in common items, such as sunscreen and tougher conductive plastics. Market research in those areas is similar to what occurs for any common-use item, and generally would never be shared competitively. For entirely new applications or new products, market research is particularly difficult, and broad industry-wide market research would more likely be shared, especially by an industry association. There may be a role for the NNI to play in creating a strong association. In addition, the long-term human and environmental health and safety aspects of nanotechnology must be examined and determined for the field to remain viable. The Federal government must take the lead in this area, spearheaded by the NNI, and supported by an industrial association, much like the chemical industry has done.

SUPPLEMENTAL MATERIALS

PROGRAM

9:15am-10:30am Session I: Energy/Petrochemicals

OVERVIEW: Does nanotechnology offer solutions to the world's energy problems? What are the relevant R&D results available now? How should the petrochemical industry embrace nanotechnology advancements to add value? How can energy companies work with research universities to leverage their R&D expenditures? Can the pace of commercialization of nanotechnology be accelerated so that large companies can expect to see a return on investment this decade? How will nanotechnology discoveries impact the range of new products in the energy/petrochemical industries? How will new nanotechnologies impact the pricing of current energy/petrochemical products? Does the energy/petrochemicals industry see nanotechnology as a revolution in new products or just the source of incremental change? If nanotechnology grows as predicted, will the United States have the workforce necessary to support nanotechnology-driven industrial growth?

Moderator:	Dr. Paul Barbara Director Center for Nano- and Molecular Science and Technology Richard J. V. Johnson Welch Chair, Chemistry University of Texas at Austin
Overview:	Dr. Altaf Carim Program Manager Division of Materials Science and Engineering Office of Basic Energy Sciences U.S. Department of Energy
Speakers:	Dr. Terry Michalske Director, Center for Integrated Nanotechnologies Department of Energy Chief, Integrated Nanotechnologies Department Sandia National Laboratories

Dr. John Stringer
Executive Technical Fellow
Science and Technology Development Division
Electric Power Research Institute

Dr. Chris Christianson
Research Fellow
Dow Chemical Co.

Dr. Lewis Norman
Manager of Research
Halliburton Energy Services

Ms. Mary Bass
Principal
Spencer Stuart

10:30am-11:00am Networking Break - Duncan Hall Lobby

11:00am-12:00pm Session II: Molecular Electronics

OVERVIEW: The information and computer revolutions of the past decades were driven by fundamental discoveries in electronic devices and integrated circuits. The nanotechnology revolution offers new directions for the electronics and computer industries. Molecular electronics has rapidly advanced from dreams to near-prototype devices. Will this technology replace silicon-based computers? Or in the short run, will there be hybrid devices that combine traditional silicon-based technologies with molecular electronics? Is there sufficient support within the venture capital community to drive a new revolution of molecular electronics? Will large existing companies be the trailblazers in molecular electronics or will the emerging industry be led by the growth of new startup companies?

Moderator: Dr. Harold Hosack
Associate Director
Materials and Process Sciences
Semiconductor Research Corporation

Overview: Dr. Brosl Hasslacher

Theoretical Physicist
Theoretical Division
Molecular Electronics Corporation

Speaker: Dr. Jim Tour
Chao Professor of Chemistry
Professor, Mechanical Engineering and Materials Science
Rice University

Dr. Herbert Goronkin
Vice President and Director
Physical Research Labs
Motorola Labs

Dr. Daniel Leff
Senior Associate
Sevin Rosen Funds

12:00pm-1:30pm Lunch
Location: Duncan Hall Lobby

Opening Speaker: Dr. Mihail (Mike) Roco
Chair
Subcommittee on Nanoscale Science, Engineering and Technology
National Science, Engineering and Technology Council
Senior Advisor, Nanotechnology
National Science Foundation

Keynote Speaker: Dr. Malcolm Gillis
President
E. K. Zingler Professor of Economics
Rice University

1:45pm-3:00pm Session III: Life Sciences

OVERVIEW: Nature has evolved marvelous nanomachines and nanosystems into the life that abounds on the earth today. Nanotechnology seeks to emulate the complexity of living systems, although the inorganic materials we use today are foreign to the water-friendly materials of life. What are the opportunities/solutions that nanotechnology offers? Can we bridge the wet-dry interface to develop the “nano-vivo” technology that will allow the next revolutions in biology, in biochemistry, in bioengineering, and especially in medicine? What are the barriers to fruitful collaborations among these very different disciplines? Are current companies well-positioned to leverage advances in medical nanotechnology or will new startup firms that focus particularly on medical nanotechnology lead commercialization? Will the venture capital community get behind medical nanotechnology the way they did with other areas of biotechnology or does medical nanotechnology represent a qualitatively new investment proposition compared to existing biotechnology? What cities will be the nation’s hubs for medical nanotechnology? How can regional communities build successful research and commercialization initiatives in medical nanotechnology?

Moderator:	Dr. James Murday Director/NNCO Naval Research Laboratory
Overview:	Dr. Robert Ulrich Founding Partner Vanguard Ventures
Speaker:	Mr. Edward M. Monachino Assistant Director for Technology Office of Technology and Industrial Relations National Cancer Institute
	Dr. Richard Gibbs Director Human Genome Sequencing Center Wofford Cain Professor Department of Molecular and Human Genetics Baylor College of Medicine Dr. Morteza Naghavi Director Vulnerable Plaque Research Texas Heart Institute

Assistant Professor
Division of Cardiology
University of Texas Health Science Center at Houston

Dr. Michael Rosenblum
Chief
Immunopharamacology and Targeted Therapy
Professor of Medicine
M.D. Anderson Cancer Center

3:00pm-4:00pm Session IV: Aerospace/Materials Science

OVERVIEW: Nanotechnology systems are based on materials and devices. What new and modified materials are emerging from current research and how soon can we produce these materials into commercial products? Where are early applications and how will they impact the aerospace industry? Can new materials-enabled devices be manufactured affordably? Will innovations be directly applicable to commercial airliners? Will new nanotechnology reduce the cost of air travel or space flight? Will new innovations in nanotechnology result in new or invigorated materials and manufacturing industries that are profitable? Will the new materials and systems enable dramatic capability improvements in the aerospace industry, or are there barriers that will limit the industry to incremental changes?

Moderator & Overview: Dr. Ken Cox
Chief Technologist
Human Exploration and Development of Space
NASA Johnson Space Center

Speaker:	Dr. Barbara Wilson Chief Technologist Air Force Research Laboratory Dr. Chester N. Kennedy Director Electronic Technology Lockheed Martin Corporation Mr. John Belk Associate Technology Fellow Phantom Works Chair Nanotechnology Steering Committee The Boeing Company Dr. Bob Gower Chief Executive Officer Carbon Nanotechnologies Incorporated
4:00pm-4:30pm	Networking Break—Duncan Hall Lobby
4:30pm-5:30pm	Group Discussion and Conclusion
Duncan Hall 1042	Energy/Petrochemicals
Duncan Hall 1064	Molecular Electronics
Duncan Hall 1070	Life Sciences
Duncan Hall 1075	Aerospace/Materials Science
5:30pm- 6:30pm	Networking Reception—Martel Hall Lobby

SPEAKER BIOGRAPHIES

Neal Lane: Dr. Neal Lane is a Senior Fellow, holding the appointment of Edward A. and Hermena Hancock Kelly University Professor at the James A. Baker III Institute of Rice University, where he is engaged in matters of science and technology policy. He also holds an appointment in the Department of Physics and Astronomy. Prior to returning to Rice University in 2001, Dr. Lane served as Assistant to President Clinton for Science and Technology, and Director of the White House Office of Science and Technology Policy (August 1998 to January 2001), as well as Director of the National Science Foundation (October 1993 to August 1998). Before becoming the NSF Director, Dr. Lane was Provost and Professor of Physics at Rice University (1986-1993). He had first come to Rice in 1966, though he left briefly (mid-1984 to 1986) to serve as Chancellor of the University of Colorado at Colorado Springs. In addition (from 1979 to 1980), while on leave from Rice, he had worked at the NSF as Director of the Division of Physics.

Richard Smalley: Professor Smalley is the Gene and Norman Hackerman Professor of Chemistry and Professor of Physics and Astronomy at Rice University. He received his B.S. in 1965 from the University of Michigan and Ph.D. from Princeton in 1973, with an intervening four-year period in industry as a research chemist with Shell before a postdoctoral period at the University of Chicago. He is known for the discovery and characterization of C60 (Buckminsterfullerene), a soccer ball-shaped molecule that, together with other fullerenes such as C70, now constitutes the third elemental form of carbon. In 1996, he shared the Nobel Prize in Chemistry for this discovery. His current research is focused on the production of continuous fullerene fibers which, just a few nanometers in width but many centimeters in length.

Paul Barbara, Moderator: Dr. Barbara is the Richard J.V. Johnson Welch Chair in Chemistry at the University of Texas at Austin. He holds his B.A. from Hofstra University. He then performed graduate work with R.G. Lawler at Brown University, and received his Ph.D. in Chemistry. He carried out postdoctoral work at Bell Laboratories and joined the faculty of the University of Minnesota in 1980, achieving the rank of full professor in 1990. In 1998 he moved to the University of Texas, Austin where he is also Director of the Center for Nano- and Molecular Science and Technology. His research interests include nanoscience, ultrafast chemical reaction dynamics in solution, radiation chemistry, photochemistry femtosecond spectroscopy, near-field scanning optical microscopy, and single molecule spectroscopy. He has published over 160 articles and book chapters.

Altaf Carim, Overview: Dr. Carim is Program Manager in the Division of Materials Science and Engineering (Office of Basic Energy Sciences, U. S. Department of Energy). Dr. Carim studied Materials Science and Engineering at MIT (B.S.) and Stanford University (M.S. and Ph.D., 1989). After brief stints elsewhere, he spent eleven years on the faculty at Penn State. He joined DOE last year, and has primary responsibility for overseeing basic research in the structure and composition of materials. He serves as a DOE representative on the NSET subcommittee of NSTC.

Lewis Norman, Panelist: Dr. Norman is Research Manager at the Halliburton Energy Services Technology Center in Duncan, Oklahoma. He holds a Ph.D. in Organic Chemistry from Texas Tech University and a B.S. in Chemistry from Panhandle State University. He completed a Postdoctoral Fellowship at Rice University in Houston.

Terry Michalske, Panelist: Dr. Michalske currently serves as Director for the Department of Energy/Center for Integrated Nanotechnologies. He also heads the Integrated Nanotechnologies Department at Sandia National Laboratories in Albuquerque, NM. He received his Ph.D. in Ceramic Science at Alfred University (1979) and was then awarded a National Research Council Postdoctoral fellowship to work at the National Institute of Standards and Technology. In 1981, Terry joined Sandia National Laboratories as a Member of the Technical Staff in the Ceramics Division. His technical interests are in the areas of interfacial phenomena, nanoscale properties of materials, and integrated microsystems.

John Stringer, Panelist: Dr. Stringer is Executive Technical Fellow in the Science & Technology Development Division at the Electric Power Research Institute (EPRI) in Palo Alto, California. He is a Fellow of a number of Technical Societies, including AAAS, TMS, ASM International, NACE International, Inst. Energy, Inst. Corrosion, and the Royal Society of Arts. He has published extensively in technical literature, with over 325 papers.

Chris Christianson, Panelist: Dr. Christianson holds his Ph.D. in Physical Organic Chemistry from Iowa State University. He joined the analytical lab at Dow Chemical in 1974. He designed urethanes in the late 70s, building what today would be called an expert system, and worked on metal fracture mechanics and corrosion, as well as establishing the fundamental structure property relationships in urethanes. He has also worked on geothermal power and hydrothermal geology, plastic fracture mechanics and stress strain curve (including the fluorocarbon membranes for the chlorine cells), trace environmental chemistry, and waste water plant start-up. He also worked on the development of new products for Dow automotive, winning the IR100 award for the strand foam energy absorbing system and design for new catalytic converter systems.

Mary Bass, Panelist: Mary's search practice focuses on Board, CEO/COO, and their direct reports for growth companies nationwide. Prior to joining Spencer Stuart, Mary had 16 years of direct investing experience with a leading private equity group in Texas. Her experience working with emerging growth companies spans several industries (telecommunications, distribution, software, specialty retail, and consumer). Mary is the past President of the Houston Venture Capital Association and is on the Steering Committee for the Dallas Private Equity Forum. She is an honors graduate of Mississippi State University, from which she earned both B.S. and M.B.A. degrees, with an emphasis on corporate finance.

Harold Hosack, Moderator: Dr. Hosack holds his PhD in Solid State Physics, with both MS and BS in Engineering Science. He is currently the Associate Director for Materials and Process Science (MPS) at the Semiconductor Research Corporation . His prior research experience is with Texas Instruments, Fairchild Semiconductor, and General Electric Corporation.

Brosl Hosslacher, Overview: Dr. Hosslacher is staff theoretical physicist in the Theoretical Division at Los Alamos National Laboratory. Originally working in high energy theory, with research in superstrings, quantum gravity and quantum field theory, his present interests include the dynamics of chaotic systems, biomorphic robotic machines, and nanotechnology as applied to computation, especially the self-assembly of electronically active systems. He has held positions at Caltech, Ecole Normal Superieure in Paris, Visiting Professor at the University of Paris, Visiting Professor of Physics at UCSD as well as senior research scientist at the UCSD Mathematics Department, and IHES in Paris. He is one of the original founders of MEC, and with Jim Tour and Mark Reed, responsible for the creation of the DARPA molecular electronics project.

Jim Tour, Panelist: Dr. Tour, a synthetic organic chemist by training, is presently the Chao Professor of Chemistry, Professor of Computer Science and Mechanical Engineering

and Materials Science in Rice University's Center for Nanoscale Science and Technology. He has over 170 research publications and 17 U.S. patents. Tour was educated at Syracuse University, Purdue University, University of Wisconsin, and Stanford University, in that order. Tour's scientific research areas include molecular electronics, molecular computing, chemical self-assembly, chemical self-replication, conjugated oligomers, electroactive polymers, combinatorial routes to precise oligomers, polymeric sensors, flame retarding polymer additives, carbon nanotube modification, synthesis of molecular motors and nanotrucks, NanoArt, and methods for retarding terrorists' use of chemical weapons of mass destruction. Tour is a co-founder, board member and officer of Molecular Electronics Corp.

Daniel Leff, Panelist: Dr. Leff is a Senior Associate with Sevin Rosen Funds, a $2B early-stage, high-tech venture capital firm. He focuses on investment opportunities in Nanotechnology, semiconductors, and advanced materials. Prior to joining SRF, Daniel worked for Redpoint Ventures and Intel Corporation. Daniel received a B.S. in Chemistry from The University of California, Berkeley and a Ph.D. in Physical Chemistry from the University of California, Los Angeles. He also holds an M.B.A. from The Anderson School at UCLA where he was an Anderson Venture Fellow.

Herbert Goronkin, Panelist: Dr. Goronkin is Vice President and Director of the Physical Research Laboratories in Motorola Labs. He received his BA, MA and PhD in Physics from Temple University. At Motorola since 1977, he has built the GaAs electronics program, led the MRAM effort, and spearheaded biotechnology and molecular electronics programs. Herb is a Fellow of the IEEE and Motorola Dan Noble Fellow, and was named Phoenix IEEE Senior Engineer of the Year in 1993.

Mihail Roco: Dr. Roco chairs the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET), and is Senior Advisor for Nanotechnology at the National Science Foundation. He also coordinates the programs on academic liaison with industry (GOALI). Prior to joining the NSF, he was Professor of Mechanical Engineering at the University of Kentucky (1981-1995), and held visiting professorships at the California Institute of Technology (1988-89), Johns Hopkins University (1993-1995), Tohoku University (1989), and Delft University of Technology (1997-98). Dr. Roco is credited with thirteen inventions, and has authored/co-authored numerous articles along with twelve books and manuals. He is a key architect of the National Nanotechnology Initiative.

Malcolm Gillis: Dr. Gillis President of Rice University and the Ervin Kenneth Zingler Professor of Economics. He received his B.A. and M.A. degrees from the University of Florida, and his Ph.D. from the University of Illinois. He began his academic career at Duke University, followed by a 15-year stint at Harvard. He returned to Duke in 1984 as professor of economics and of public policy. In July of 1993, he became the sixth president of Rice University. Until assuming leadership roles in University administration, he was a frequent consultant to the U.S. Treasury Department, the Canadian Ministry of Finance, the World Bank, and the governments of Colombia, Ecuador, Bolivia, and Indonesia. He has published over 70 articles, and is author, co-author, or editor of eight books.

James Murday, Moderator: Dr. Murday received his B.S. in Physics from Case Western Reserve, and Ph.D. in Solid State Physics from Cornell. He joined the Naval Research Laboratory (NRL) in 1970, led the Surface Chemistry effort from 1975-1987, and has been Superintendent of its Chemistry Division since 1988. From May to August 1997 he served as Acting Director of Research for the Department of Defense, Research and Engineering. His research interest in nanoscience began in 1983 as an Office of Naval Research program officer and continues through the NRL Nanoscience Institute. He is Executive Secretary to the U.S. National Science and Technology Council's Subcommittee on Nanometer Science Engineering and Technology (NSET) and Director of the U.S. National Nanotechnology Coordinating Office.

Jack Gill, Overview: Dr. Gill is a 35-year veteran of Silicon Valley and has founded numerous successful companies in the medical, instrumentation, computer, and communications industries. He co-founded Vanguard Ventures in 1981. Vanguard's first five funds invested $155 million in 103 startups and generated $1.3 billion return to investors. Successes include Aldus, Endosonics, Endotherapeutics, Indigo Medical, Mycogen, CardioGenesis, Advanced Fibre Communications, Ciena, Digital Microwave, Tut Systems, Cobalt Networks, and Digital Island. In early 2000, Dr. Gill moved to Boston and joined the faculty of HMS and is the senior advisor to the Harvard-MIT-CIMIT program. He also teaches courses in entrepreneurship at MIT, Stanford, Rice, Texas, and Indiana University.

Michael Rosenblum, Panelist: Dr. Rosenblum graduated from the University of South Carolina with a B.S. in Chemistry in 1972 and received his M.S. degree in Pharmacology from the Medical University of South Carolina in 1974. He received his Ph.D. degree in Biochemical Pharmacology from the University of Arizona in 1978. Dr. Rosenblum is a

Professor of Medicine at MDACC and is Chief of the Section of Immunopharmacology and Targeted Therapy. His research is focused on development of novel targeted therapeutics (" Smart Drugs") both for leukemia and solid tumors.

Richard Gibbs, Panelist: Dr. Gibbs received a B.S. (*cum laude*, 1979) and a Ph.D. (1986) in Genetics and Radiation Biology from the University of Melbourne. He subsequently moved to Houston as a postdoctoral fellow at the Baylor College of Medicine to study the molecular basis of human X-linked diseases and to develop technologies for rapid genetic analysis. During this period he also developed several fundamental technologies for nucleic acid analysis. In 1991, he joined the faculty at BCM and played a key role in the early planning and development phases of the human genome project. In 1996, he established the Human Genome Sequencing Center when Baylor was chosen as one of six programs to complete the final phase of the human genome project. In addition to his work on the human genome project, Dr. Gibbs has also made significant contributions to the deciphering of the fruit fly, mouse, *Dictyostelium*, and rat genomes.

Morteza Naghavi, Panelist: Dr. Naghavi is a graduate of Tehran University, where he led a number of research studies on risk factors of coronary heart disease that led to the foundation of Cardiovascular Research Center in Tehran University. He joined the faculty of the Division of Cardiology at the University of Texas-Houston in 1998. He is currently Assistant Professor and Co-Director of Center for Vulnerable Plaque Research at the Texas Heart Institute and University of Texas Houston. Dr. Naghavi's research is now focused on the early detection and treatment of vulnerable plaques/patients. He is studying novel intravascular and noninvasive imaging techniques for screening inflamed atherosclerotic lesions. Dr. Naghavi has invented thermography and spectroscopy catheters for temperature and pH measurement of atherosclerotic plaques.

Edward Monachino, Panelist: Mr. Monachino is Assistant Director for Technology in the Office of Technology and Industrial Relations (OTIR) of the National Cancer Institute (NCI). He manages technology development programs implemented through the OTIR which are focused on the development of novel molecular analysis technologies for the detection, treatment, and monitoring of cancer in its earliest stages. Mr. Monachino has held the position of Program Manager in support of several offices and technology development programs at the Defense Research Projects Agency (DARPA) and the Ballistic Missile Defense Office (BMDO). Prior to that, Mr. Monachino held a position as Senior Architect at the General Electric Company. He received his Bachelor's degree from Clarkson University, and his Master's degree from Syracuse University.

Ken Cox, Overview & Moderator: Dr. Cox is an engineer, technologist, scientist and change agent working for NASA JSC for more than 35 years. He received his B.S. and M.S. in Electrical Engineering from the University of Texas and his Ph.D. from Rice University. Ken served as technical manager for the Apollo primary flight control systems in the early 1960s. His awards include the AIAA Mechanics and Control of Flight Award (1971) and the AIAA Digital Avionics Award (1986).

Bob Gower, Panelist: Dr. Gower is CEO of Carbon Nanotechnologies, Inc. He received his bachelor's and master's degrees from Southern Illinois University, and his doctorate (in organic chemistry) from the University of Minnesota. Dr. Gower first joined Sinclair Oil Corporation and advanced through a number of sales, research and engineering assignments with Sinclair and Atlantic Richfield after the merger of the two companies. He became Vice President of ARCO Chemical Company in 1977 and Senior Vice President in 1979. In June, 1984 he was elected to Senior Vice President of Atlantic Richfield Company. In 1985, he became the founding President of Lyondell Petrochemical. He was made CEO in 1988 and Chairman of the Board in 1994. He is currently a member of the Board of Directors of Kirby Corporation, Omnova Solutions, Inc. and CheMatch.com.

John Belk, Panelist: Mr. John H. Belk is responsible for harvesting leading edge technologies from the Boeing Company's venture capital fund investments. He holds six U.S. patents and has contributed to new manufacturing processes for composite materials, optical fiber sensors for smart structures and process control, MEMS-based sensing systems, and satellite-to-satellite laser communications.

Chester Kennedy, Panelist: Mr. Kennedy currently serves on the corporate staff at Lockheed Martin Corporate Headquarters in Bethesda Maryland where he is responsible for providing strategic advice and guidance to top corporate executives on all matters relative to the corporation's broad interests in Electronic Technology. Prior to joining the corporate staff, Chester spent 15 years in the corporation's Missiles & Fire Control operations where his assignments included directing the divisions extensive Research &Technology efforts.

Barbara Wilson, Panelist: Dr. Wilson is Chief Technologist, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio. Dr. Wilson assists in managing the technical content and quality of the Air Force's science and technology portfolio's annual $1.3 billion budget and additional $1.1 billion from laboratory customers. She holds a B.A. in Physics (*summa cum laude*) from Mount Holyoke College, and a Ph.D. in Condensed Matter Physics from the

University of Wisconsin-Madison. Dr. Wilson began her career at AT&T Bell Laboratories in 1978. In 1988, she moved to the NASA Jet Propulsion Laboratory, where she held various management and leadership positions. Dr. Wilson served on two Air Force Scientific Advisory Boards, and has participated on a number of National Science Foundation boards for selecting and reviewing Engineering Research Centers.

WELCOMING REMARKS BY NEAL LANE

Dr. Neal Lane
University Professor
Edward A. and Hermena Hancock Kelly Senior Scholar
at the James A. Baker III Institute for Public Policy
Professor of Physics and Astronomy
Rice University

Good morning, everyone, and welcome to this “Nanotechnology Workshop – From the Laboratory to New Commercial Frontiers.” We have an exciting program of speakers and should have a very productive workshop. I want to welcome, not only our audiences here in Duncan Hall’s McMurtry Auditorium, but also our overflow audiences in nearby classrooms, our video audience watching on Rice closed circuit television, and especially our web-cast audience across the country, who should have an opportunity to submit emailed questions to our panels later in the program.

A WORD OF THANKS

Before we begin our program, I want to take this opportunity to thank our sponsors – The National Nanotechnology Coordinating Office, the U.S. Department of Commerce, the National Science Foundation, the Department of Energy, and the Federal Aviation Administration.

And our hosting organizations:

Rice Alliance for Technology and Entrepreneurship,
Professor Steve Currall, Director

Rice's Center for Nanoscale Science and Technology
Dr. Wade Adams, Director

James A. Baker III Institute for Public Policy of Rice University,
Ambassador Edward P. Djerejian, Director

And a special thanks to the organizing committee listed in your program booklet, especially Carlos Garcia and Trish Leggett, the real workers behind the event, and to our special crews of nano-enthusiasts, from high school students to Rice staff members.

PURPOSES OF THE WORKSHOP

The stated PURPOSES of the Regional NNI Workshops are to:
a) Increase awareness of the NNI and nanotechnology throughout the entire country.
b) Accelerate commercialization of nanoscience and nanoengineering.
c) Provide feedback to NNI about needs, new directions and initiatives, especially for commercialization.

QUESTIONS

Given the list of experts we have as participants at this workshop, we will have not shortage of wisdom. But, just to lay some ideas on the table, let me pose some questions you might consider along the way.
1. What actions could be taken by the NNI to accelerate the transition of science discovery into new technology?
2. Should the NNI have programs for which companies can compete for Federal nanotechnology funding? How should they be structured (e.g., something like the Advanced Technology Program, or SBIR/STTR, or something new)?
3. In order to help companies best exploit nanoscience discoveries, what information should the NNI make available on its homepage: www.nano.gov

Would an information booklet for industry make sense? If so, what should it include?
4. For the focus topics (energy and petrochemical, molecular computing, life sciences, aerospace and materials) are there un-funded, or under-funded scientific opportunities that the NNI should address?

5. Do nanoscience, nanoengineering and nanotechnology need standards and, if so, how should they be established? Should NIST assume the leadership role nationally and internationally, in setting such standards?

6. It has been stated that nanotechnology will need 2 million new and trained workers over the next ten years. How should that large need for technologically skilled human capital be created?

7. What changes, if any, in the administration or organization of the NNI are needed? How can the NNI be more effective in "leading" the nation's nanotechnology revolution?

FINAL COMMENTS

Let me just add a personal note.

One of the things I most enjoyed in my time in the White House was having a role in the establishment of the National Nanotechnology Initiative. I got to work with terrific people in the agencies, like Mike Roco at NSF, and in the White House, as well.

President Clinton was very excited about this initiative, which as you know, he placed prominently in his FY01 budget, requesting a doubling of funds for Federal research in nanoscale science and engineering, and large increases for all fields of research, in an effort to address the serious imbalance that has developed between funding for biomedical research and all other areas, the physical sciences and engineering, in particular.

President Bush also places a high priority on nanoscale R&D and the Congress is enthusiastic as well—both sides of the aisles.

But, we need to do much more than we are doing. Japan has identified nanotechnology as one of its principal priorities for the next five years or so; and it is considering a goal of $ 2 billion/year for nanoscale science and engineering by the year 2005. This is double what the U.S. plans to invest.

When I was in China, last November, I met with President Jiang Zemin. One thing he wanted to talk about was nanotechnology and to tell me about the ambitious efforts planned for China.

Every nation of the world is looking at nanotechnology as the future technology that will drive their competitive position in the world economy. The U.S. cannot afford to let this one slip away!

We need to support the coordinated efforts of the NNI, argue strongly for significant growth in funding for research in the physical and life sciences, outside of biomedical research, and in engineering.

We should have in place particularly ambitious plans and budgets for nanoscale science and engineering, across the entire spectrum – from the most fundamental research, to technological development, to commercialization, including partnerships with industry.
And, we need to make sure we have the skilled workforce to do all this. That's why it is so critical that the overall Federal support for research grow significantly over the next decade or so. Our elected representatives in Washington need to hear from us and our partners in the private sector.

Once again, thank you all for being here. I look forward to a most fruitful workshop.

It is now my pleasure to begin the Plenary Session of this workshop. Our first speaker is the Honorable Phillip Bond, the Under Secretary of Commerce for Technology. The Commerce Department is playing an increasingly important role in this nation's nanotechnology revolution, and Phil Bond is the emerging leader from the Commerce Department to spearhead more federal government action in support of nanotechnology. As you can see in his biography in the program, his background in information technology in the private sector as well as his experience in legislative affairs gives him the credentials needed to get things done for the good of American industry and for the people of the United States.

The Honorable Phillip J. Bond
Chief of Staff and Under Secretary for Technology
U.S. Department of Commerce

Dr. Lane continued: Our next speaker needs no introduction to most of you in the audience, but for those of you visiting for the first time, I am most pleased to introduce Professor Richard Smalley. The co-discoverer of the bucky ball (C60, or Buckminsterfullerene), for which he received the Nobel Prize in Chemistry, the founder of the Rice Quantum Institute and the Center for Nanoscale Science and Technology at Rice, and the founder of the company poised to start production of usable quantities of carbon nanotubes, Rick was also one of the original committee members who started the NNI itself. He continues working today to introduce nanotechnology to the public as well as doing his own research in single walled nanotubes.

ATTENDEES LIST AND DEMOGRAPHICS

Name	Affiliation	Location
Oddvar Aaserud	Venturos Venture	Norway
Douglas Adam	Northrop Grumman	MD
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Anna Ahrens	Rice University	TX
Cyrus K. Aidun	National Science Foundation	VA
Maurice Amateau	Pennsylvania State University	PA
Paul Amirtharaj	Army Research Lab	MD
William Andahazy	University of South Carolina, Columbia	DC
David Anderson	Technology Strategies and Alliances	VA
Stephen Anderson	PennWell	NH
Anthony Andrady	Research Triangle Instititute	NC
Rodney Andrews	University of Kentucky	KY
Tim Andrews	Chattannooga Area Chamber of Commerce	TN
Tim Appaiah	George Washington University	VA
Sivaram Arepalli	NASA-Johnson Space Center	TX
Jean-Pierre Arlie	Institut Francais du Petrole	France
Eugene Arthurs	SPIE (Int'l Society for Optical Engineering)	WA
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Abdelhak Bensaoula	Texas Center for Superconductivity and Advanced Materials	TX
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Juergen Berger	VDI/VDE-Technologiezentrum Informationstechnik	Germany
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Rob Bishop	nanoTiTan Inc.	VA

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Doublas Burke	National Defense University	DC
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Gary Burns	Dow Corning Corporation	MI
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Shannon Carpenter	Rice University	TX
Dustin Carr	Lucent Technologies	NJ
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Jaewu Choi	Wayne State University	MI
Stephen Chou	Princeton University	NJ
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Jonathan Fink	Arizona State University	AZ
Lynn Foster	Larta University	CA
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Jayne Fried	Small Times Media	CA
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Virendra Sarohia	Jet Propulsion Lab.	CA
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Jim F. Saultz	Lockheed Martin Advanced Tech. Labs.	NJ
Norman Saunders	Technology Strategies and Alliances	VA
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Jane W. Schweiker	IEEE	NJ
Sudipta Seal	University of Central Florida	FL
Ali Shadman	JK&B Capital	IL
Stephen Shea	BP Solar	MD
Michael Sheldon	ETF Group, Inc.	CT
Richard Shi	University of Washington	WA
Soey Sie	CSIRO Exploration & Mining	Australia
Nina Siegler	Johns Hopkins University	MD
Thomas Siegmund	Purdue University	IN
Cylon Silva	Laboratório de Luz Síncrotron	Brazil
N. B. Singh	Northrop Grumman	MD
Vijay Singh	University of Kentucky	KY
Richard Slusher	Lucent Technologies	NJ
Richard Smalley	Rice Univ	TX
Sharon Smith	Lockheed Martin Corporation	MD
Richard Smith	Coates & Jarratt, Inc.	DC
Wayne Smith	RAVE LLC	TX
Ken Smith	Carbon Nanotechnologies, Inc.	TX
Bruce Snider	Raytheon	TX
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Dexter D. Snyder	General Motors R&D	MI
Elissa Sobolewski	NIST/ATP	MD
Brett Solberg	Rice University	TX
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Lee H. Spangler	Montana State University	MT
Christopher J. Stanton	University of Florida	FL
Judith Stein	GE Global Research Center	NY
Christian Stich	Toucan Capital Corp.	MD
Paul Stone	Michigan Molecular Institute	VA
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Ken Stubblefield	Small Times Media	MI
Barry Sullivan	International Engineering Consortium	IL
Mahendra Sunkara	University of Louisville	KY
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Dor Ngi Ting	SurroMed Pte Ltd	Singapore
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Jim Tour	Rice Univ	TX

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Darrin Young	Case Western Reserve University	OH
Sharon Yun	US Department of Commerce	DC
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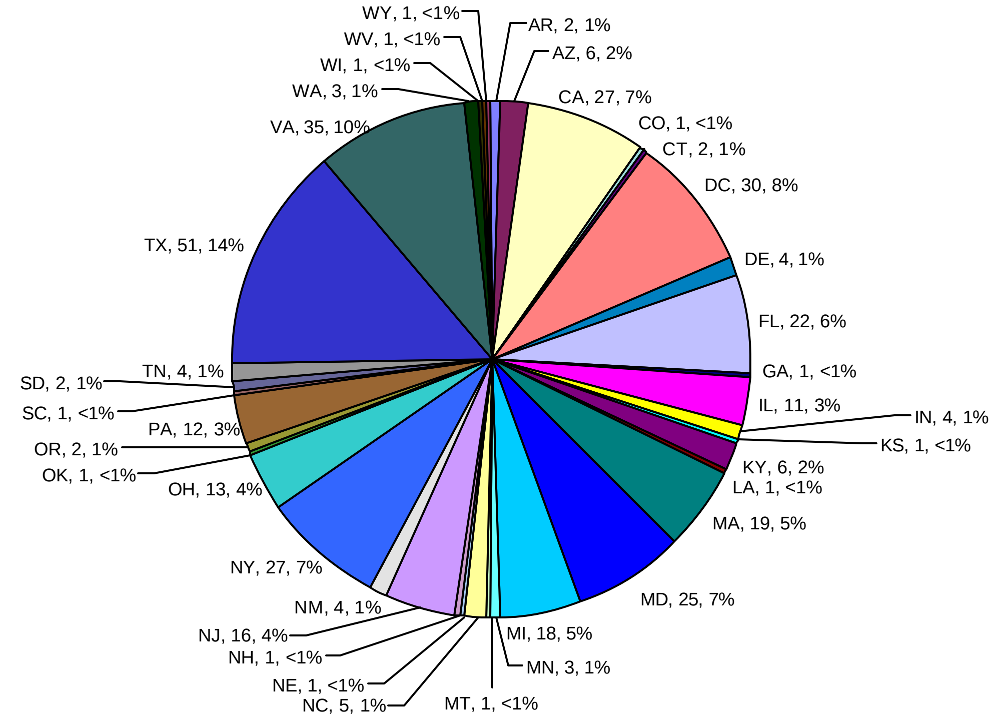
Mengjun Zhang	Science & Technology Daily	VA
Yafei Zhang	Shanghai Jiao Tong University, Rsrch. Inst. for Micro/Nano	China
Z. John Zhang	Georgia Institute of Technology	GA
Jane Zhu	New Mexico State University	NM

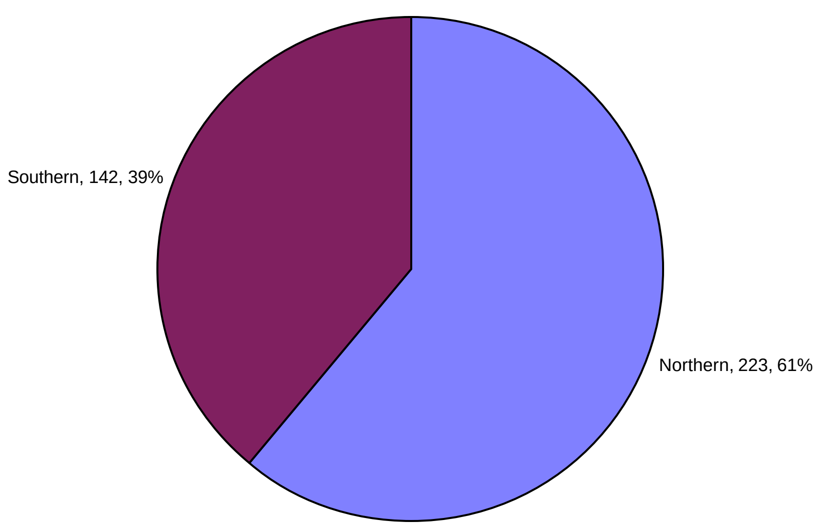
U. S. Attendees by State

365 U.S. Attendees comprised 90% of 406 Total Attendees
37 states and the District of Columbia were represented

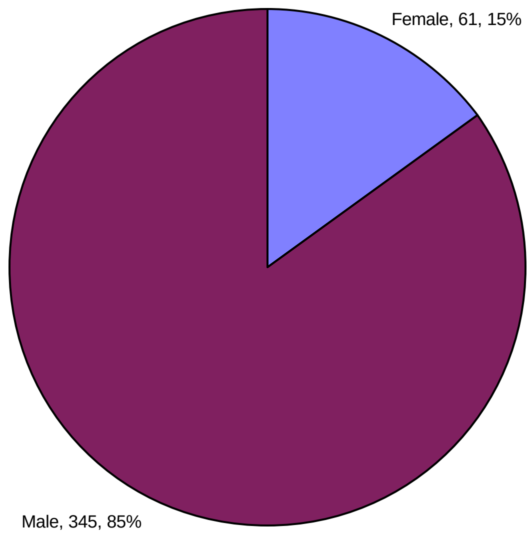


U. S. Attendees by Region

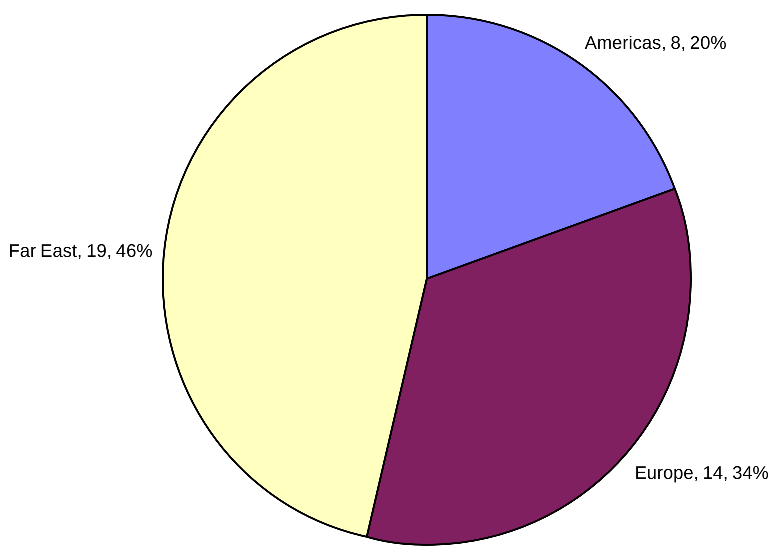
Southern Region: AR, AZ, CO, FL, GA, KS, KY, LA, NC, NM, OK, SC, TX, TN, VA, WV
Northern Region: CA, CT, DC, DE, IL, IN, MA, MD, MI, MN, MT,NE, NH, NJ, NY, OH, OR, PA, SD, WA, WI, WY

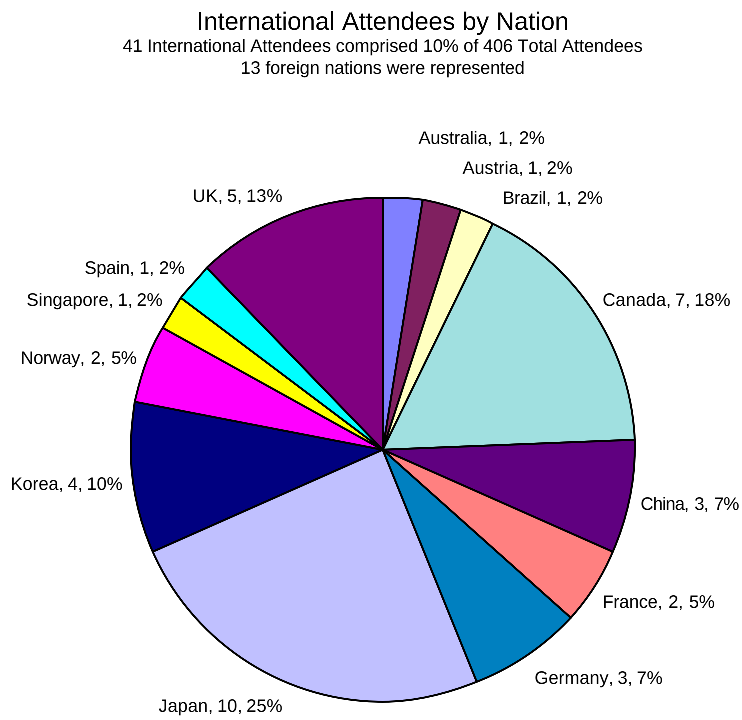


Attendees by Gender
of 406 Total Attendees



International Attendees by Region
41 International Attendees comprised 10% of 406 Total Attendees




International Attendees by Nation
41 International Attendees comprised 10% of 406 Total Attendees
13 foreign nations were represented
Australia, 1, 2%
Austria, 1, 2%
Brazil, 1, 2%
Canada, 7, 18%
China, 3, 7%
France, 2, 5%
Germany, 3, 7%
Japan, 10, 25%
Korea, 4, 10%
Norway, 2, 5%
Singapore, 1, 2%
Spain, 1, 2%
UK, 5, 13%

PRESS RELEASES AND INTERVIEWS

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NANOTECH MEETS MARKET REALITIES

Nanotechnology developers are aspiring to the daunting challenge of commercialization

ANN M. THAYER, C&EN HOUSTON

Almost three decades ago, fullerenes were identified in sootlike substances produced at Rice University in Houston. Only today, after nearly 20 years of study, are laboratory processes being improved and scaled up to produce fullerenes and related carbon nanotubes in 100-g quantities that should bring prices down under a few hundred dollars per gram.

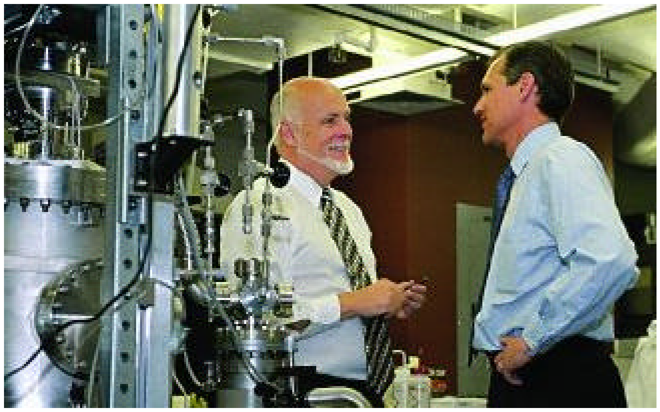
But that's still a far cry from commercialization. "Most materials at volume--say, a billion pounds per year or so--are less than $1.00 per lb," pointed out Dow Chemical research fellow Chris Christenson at a National Nanotechnology Initiative (NNI) regional workshop in May at Rice. "We can't get there shooting lasers at graphite blocks."

Commercial-scale production of fullerenes and nanotubes in kilogram-per-day amounts is still at least a year away. However, some industry pundits are already calling fullerenes and other materials--such as nanotubes, metals, and clays finding limited use in composite materials and coatings--the "mature" side of nanotechnology.

Nanotechnology, including these nanoscale materials, is being touted as the next industrial revolution, with long-term and wide-ranging effects on many products and industries. The U.S. government goes as far as suggesting that in just another 10 to 15 years, nanotechnology will impact more than $1 trillion per year in products and services.

Based on a broad definition that considers most of biotechnology the "wet side" of nanotechnology, Rice chemistry professor and Nobel Laureate Richard E. Smalley likes to say that "it holds the answer, to the extent there are answers, to most of our most pressing material needs in energy, health, communication, transportation, food, water, et cetera."

However, to have a great impact, nanotechnology must not only yield expensive products for possible high-end applications, but also inexpensive products for large-volume uses, Christenson cautioned. Meeting these market needs means overcoming some sizable technological challenges.



BIG DREAMS
Nobel Laureate Smalley (left) describes the research at Rice University's Carbon Nanotechnology Laboratory to Bond, undersecretary of commerce for technology. RICE PHOTO

The desired properties that nanomaterials must offer, such as both stiffness and toughness, are "contradictions" and thus often difficult to achieve in combination, Christenson explained. "Success is delivering the properties we need at the right price, and that price is low," he added. "You must also be able to make products quickly using low-cost starting materials."

While nanomaterials are starting to find limited application, the timescale for commercializing nanoelectronics, another broad branch of the field, is much longer. Within a few years, the closest products are expected to include displays and field emission devices, followed a year or two later by chemical and biological sensors and optical components. But the holy grail in nanocomputing, namely memory and logic devices, is still at least a decade away.

"Substantial and sustained national investment is going to result in some exciting scientific and technological breakthroughs, and those are going to lead to commercialization and fuel economic growth," said Phillip J. Bond, U.S. undersecretary of commerce for technology, at the NNI workshop.

He reported that 93% of commercial and 58% of academic labs working on nanotechnology believe they are going to have a product or service in the next year. Yet, Bond warned, "we shouldn't be seduced by the hype, especially in the post-dot-com world. Let's keep these developments in perspective--near term they are going to be incremental, not fundamental."

Still, interest in nanotechnology has skyrocketed, and it's hard to turn around without falling over a conference or report on the subject. The meetings typically involve academic, government, and a few industrial researchers, along with some venture capitalists and very early stage ventures looking for start-up company funding.

The mood these days--as at the NNI workshop, Nanotech Planet conferences in the U.S. and Europe, National Institute of Standards & Technology Nanotechnology Open House, NanoSpace 2002, and other events held this spring and summer--is an odd mix of hype, hope, and an increasingly large dose of reality in facing technological, business creation, and commercialization hurdles.

"Nanotechnology is an awful lot of hype," said Conrad Masterson, chief executive officer of NanoTex Foundation, at NanoSpace 2002 in late June. "And the biggest part of the hype comes from the conference planners who are doing venture-capital and investment discussions." Through the nonprofit NanoTex, Masterson is hoping to pull together $50 million in private monies to support academic research in Texas.

"We're dealing with something that's misnamed--we're talking about science in most cases, not technology or commercialization," he added. "That's not to say that there won't be great investment and commercialization opportunities, but those will be more in the future." He pointed to the earlier example of semiconductor technology, which took decades to have a broad impact.

Others blame the media for the hype. However, while conference speakers attempt to focus on more realistic expectations, they still toss out billion-dollar market estimates along with the phrases "industrial revolution," the "next Silicon Valley," and "Intel of the future."

"Politically, hype is necessary," Bond admitted. "Melding hype and hope creates social passion that forms our policies. It gets budgets passed so that the NNI can be funded." He noted that the U.S. federal budget proposal for fiscal 2003 includes a 17% increase in NNI funding to about $710 million. Many consider three-year-old NNI not only to have jump-started the U.S. nanotech push, but also to have spurred other nations to formulate plans.

Government spending continues to be the largest supporter of nanotech R&D worldwide, having grown nearly fivefold in the past five to six years. According to frequent conference speaker Mihail C. Roco, National Science Foundation senior adviser for nanotechnology, the U.S. now represents about 27% of worldwide government spending on nanotechnology. In the past few years, Japan has taken the lead.

The rate of growth in U.S. spending also has slowed while other countries' spending has increased, leaving many in the nanotech community fearing that the U.S. is nearing a plateau in its willingness to invest. At least 30 countries have initiated or are beginning national activities, reports Roco, who also chairs the National Science & Technology Council's Nanoscience, Engineering & Technology Subcommittee.

Roco sees the need for and is working on a coherent, longer term plan for NNI, looking out five to 10 years, to present to Congress. In mid-June, the National Research Council made its recommendations to bolster NNI's efforts (C&EN, June 17, page 19).

"Japan has identified nanotechnology as one of its principal priorities," Neal Lane, a Rice University physics professor and former presidential science adviser, told attendees at a recent meeting. "Every nation in the world is looking at nanotechnology as a future technology that will drive its competitive position in the world economy. The U.S. simply cannot afford to let that opportunity slip away."

In mid-June, the European Commission announced that it would invest about $700 million in nanotech research over four years (C&EN, June 24, page 18). "Enterprises cannot do everything on their own," said EU Research Commissioner Philippe Busquin when announcing the program to coordinate and support R&D. "The challenge is so big that it has to be faced by solid public-private partnerships."

International efforts are being created, such as the alliance between the U.S. and Europe for research cooperation. Business associations, such as the NanoBusiness Alliance in the U.S., the European NanoBusiness Association, and the Asia-Pacific Nanotechnology Forum, have emerged to promote the industry. Activity is heating up at the regional, state, and local levels as well, with commitments by some U.S. states approaching $100 million.

In Texas, a consortium of industry, universities, government, and venture capitalists has created the nonprofit Texas Nanotechnology Initiative. It anticipates that about $1 billion will be invested in developing and applying nanotech in Texas over the next five years. The organization's goal is to bring companies, researchers, and funding together to "create an environment for rapid commercialization."

While the triangle formed by Houston, Dallas, and Austin has been nicknamed the "nanoprairie," Southern California has its "nanorepublic," created by the Los Angeles Regional Technology Alliance. It brings together corporate, university, and other technology leaders to "identify issues and impediments in the nanoindustry of California." Targeted nanotech programs exist in the Silicon Valley and San Diego areas, as well as in New York, Pennsylvania, Illinois, Denver, Virginia, and Michigan.

Much activity in the U.S. has revolved around government-sponsored centers--such as NSF's six university-based nanoscale science and engineering centers, the National Aeronautics & Space Administration's three nanoscience centers, and the Department of Energy's nanoscience labs. Rice, Cornell University, and Northwestern University already house NSF centers, but, like several other universities, they are setting up their own nanoscience research institutes as well.

Government and university research efforts are attracting the attention of civic and economic development groups. For example, the Houston Technology Center, which assists small start-up companies, has been promoting nanotechnology locally, based on the strength of Rice's efforts. Meanwhile, Chicago's administration has embraced nanotech as a key part of the economic development strategy for greater Chicagoland.

Rice is the first university to have a broad-based strategy toward nanotechnology, Rice President Malcolm Gillis told more than 500 attendees at the Houston Technology Center's forum this spring. He called nanotechnology an "infant industry" that will fill the role of past growth industries--such as oil and gas, petrochemicals, and electronics--for Houston.

Rice alone has filed more than 156 nanotech patent applications, created four start-up companies, and is working on three more, Gillis said. As many as 18 companies have set up shop across the state. Worldwide, there are already 440 nanotech companies, according to nanotech consultancy CMP Científica. About 230 are in the U.S., another 130 are in Europe, and about 80 are in the Asia-Pacific region.

"The model for nanotechnology is similar to that for biotechnology," said Rice chemistry professor Vicki L. Colvin at NanoSpace 2002. "Small start-ups, rather than licensing to large companies, are the rule, not the exception."

Colvin is also executive director of the Center for Biological & Environmental Nanotechnology, the NSF center at Rice. Realizing that commercialization timescales are long and markets uncertain, the university and its centers provide assistance in manufacturing scale-up, business creation, and human resource development.

Entrepreneurs from some nanotech start-ups and venture capitalists offered their advice at the recent meetings on starting and funding companies. Estimates are that only about $200 million of private money has gone into nanotech start-ups to date, according to Robert D. Ulrich of Vanguard Ventures.

"It would be real easy to bash the venture capitalists because their record for investing over the last few years hasn't been so great," said Louis C. Brousseau, CEO of Quantum Logic Devices. "But there's not really a place for them right now as nanotech doesn't fit their model--it's too high risk. There's too much yet to be uncovered and yet to be done, and it doesn't pay off quickly."

Others agreed and pointed to other funding, such as government small business grants, that can help to move very early stage science to a point where proof of concept or prototypes can help make a business' case and attract investors. Besides a viable business plan, developers should address technical, product application, market, and manufacturing issues early, they said.

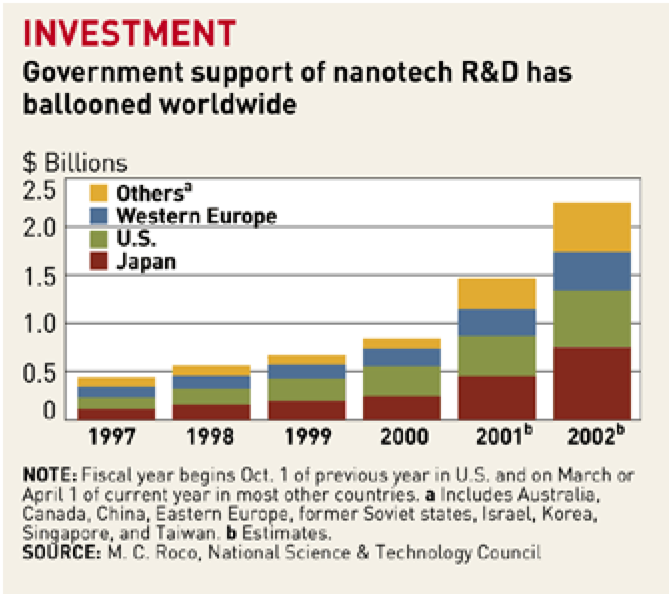
While nanotechnology may be exciting science, many proposed business models and strategies lack clarity and long-term value, said Daniel Leff, senior associate with Sevin Rosen Funds. "It's often tough figuring out where the business is--simply answering the questions: What can you build? Who will buy it? And what will they pay for it?

"It's okay if the timelines are three, four, five, or six years, but there has to be a coherent strategic plan and product development focus, rather than uncertainty around feasibility," he said.

Tim Belton, consultant and former president and chief development officer of Rice spin-off Molecular Electronics Corp., tried to put things in perspective for NanoSpace 2002 attendees.

"Most venture investors today are more confident that they can generate better returns faster with other investment opportunities than nanotechnology," he warned. "What dominates your perspective of what is going to change the world is only one of many stories that an investor is going to hear that day."

Thus Belton and the other speakers also listed patience, persistence, and realistic expectations among valuable qualities for would-be entrepreneurs who hope to move nanotechnology beyond the hype and into the industrial realm.



Rice News Release
THE RICE UNIVERSITY WEEKLY ONLINE

Rice University
Office of News & Media Relations

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NANO RESEARCH, ITS POTENTIAL FOCUS OF EVENT

Some 400 leading nanotechnologists met at Rice May 23 for the National Nanotechnology Initiative's (NNI) Southern Regional Workshop, a one-day gathering aimed at developing new ways to foster commercialization of federally funded nanotechnology research.

The workshop, which drew experts from academia, government, industry and finance, was the second of four regional NNI meetings planned in the United States this year. It featured presentations in four research areas: energy/petrochemical, molecular electronics, life sciences/biotechnology and aerospace/materials science.

The workshop was presented by the Rice Alliance for Technology and Entrepreneurship, the Center for Nanoscale Science and Technology (CNST) and the James A. Baker III Institute for Public Policy. Sponsors included the U.S. Department of Commerce, the U.S. Department of Energy, the Federal Aviation Administration, the National Science Foundation and the National Nanotechnology Coordinating Office.

In describing the potential economic impact of nanotechnology in the century ahead, Rice President Malcolm Gillis drew an analogy to the chemical industry's legacy from the 20th century.

"Development of that industry helped accelerate growth in dozens of others, including oil and gas refining, pulp and paper, textiles, building materials and, of course, pharmaceuticals," Gillis said, noting that nanotechnology is the basis of several nascent industries that stand to play a similar role in the 21st century.

The workshop focused on identifying ways that the NNI can foster those industries by better commercializing the research it's funding. The NNI is a broad-based federal research initiative that is funding more than $600 million in nanoscale research this year. President Bush has asked Congress for $710 million in NNI funding for 2003.

Government and corporate leaders pointed to the flurry of nanotech startups as a sign of the increasing commercial potential for nanotechnology. Having been at the fore of nanoscale research for more than a decade, Rice already has spawned four nanotech startup companies, with three more in the works, Gillis noted. The Rice Alliance is playing a key role in moving Rice's research from the lab to the marketplace.

But national leaders also cautioned that the public won't see a significant impact from nanotechnology in their daily lives for some time to come, which has led critics to complain that nanotechnology is being overhyped in the press.

"I agree with the notion that we shouldn't be seduced by the hype, and we shouldn't let 'nano' become a four-letter word, but a certain amount of hype and exuberance is needed to get people interested," said Phillip J. Bond, undersecretary of technology at the Commerce Department. "Nanotech-nology does hold the answer — to the extent that there are answers — to most of our most pressing material needs."

Bond said the real fruits of nanotech-nology are more likely to benefit his preteen daughters than himself, a notion that was confirmed by other speakers. In a noon keynote, NNI Director Mihail Roco said the NNI will continue to focus primarily on fundamental research for the next four to five years. Roco said nanoscale research to date has resulted in "islands" of knowledge, and more research is needed to tie together findings in various areas and increase the overall understanding of basic nanoscale science.

Moving forward, Rice continues to build upon its pre-eminent position as a hotbed of nanotech innovation. More than a dozen Rice researchers are presenting research this week in Galveston at NanoSpace 2002, an annual conference co-sponsored by Rice, NASA and others that brings together aerospace, nanotechnology and biomedical researchers.

In addition, Rice's CNST (http://cnst.rice.edu) and NanoTex (www.nanotex.org), a privately funded research initiative that promotes nanotechnology in Texas, will co-host a one-day workshop on nanotechnology and medical technology Aug. 1 at the Hornberger Conference Center in the Texas Medical Center. The meeting aims to foster communication between researchers in the natural sciences and life sciences.

Rice News Release
THE RICE UNIVERSITY WEEKLY ONLINE

Rice University
Office of News & Media Relations

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NANOTECH EXPERTS DISCUSS WAYS TO COMMERCIALIZE RESEARCH

NNI Leaders Meet May 23 at Rice for One-day Workshop on Commercialization, Policy

Leading scientific researchers, government officials, industry executives and financial investors will meet May 23 at Rice University to discuss ways to foster commercialization of federally funded nanotechnology research. About 300 nanotechnology experts are expected to attend the National Nanotechnology Initiative's southern regional workshop titled "Nanotechnology: From the Laboratory to New Commercial Ventures."

The event is the second of four regional workshops that aim to gather input about future NNI policy and funding priorities. NNI funding this year will exceed $600 million, and President Bush has asked Congress for $710 million in NNI funding for 2003. Nanoscale science and technology involve the observation, manipulation and/or assembly of biological and inorganic materials at a molecular or atomic level.

This workshop will focus on ways that NNI can foster commercial opportunity and increase collaboration among academia, industry and government. Speakers include NNI director Mihail Roco, former White House science adviser Neal Lane, Commerce Department Under Secretary for Technology Phillip J. Bond and Nobel laureate chemist Richard Smalley. In addition, panels of experts will discuss four specific research areas: energy/petrochemical, molecular electronics, life sciences/biotechnology and aerospace/materials science. Topics of discussion will include:

- Major technical challenges arising from nanotechnology
- Trends in nanotechnology that industry has yet to fully comprehend
- Major obstacles to investment and development of nanotechnology
- Education and training resources needed to produce the next generation of nanotechnology researchers and engineers

The workshop is organized by the Rice Alliance for Technology and Entrepreneurship, Rice's Center for Nanoscale Science and Technology and Rice's James A. Baker III Institute for Public Policy. Sponsors include the U.S. Department of Commerce, the U.S. Department of Energy, the Federal Aviation Administration, the National Science Foundation and the National Nanotechnology Coordinating Office.

The workshop will take place in Duncan Hall at Rice University. The event is free, but seating is limited. Registration information and a program schedule are available online at http://www.alliance.rice.edu.

About the speakers:
Roco, a key architect of the NNI, is chairman of the National Science and Technology Council's Subcommittee on Nanoscale Science, Engineering and Technology, and is also Senior Adviser for Nanotechnology at the National Science Foundation.

Under Secretary Bond is the principal technology adviser to Commerce Secretary Donald Evans and also serves as his Chief of Staff. Bond supervises technology policy development and direction in three Commerce agencies – the Office of Technology Policy, the National Institute of Standards and Technology (NIST), and the National Technical Information Service (NTIS), and coordinates tech policy throughout the department. He serves on four committees of the President's National Science and Technology Council.

Lane is a university professor at Rice and a senior fellow at the Baker Institute. A former director of the National Science Foundation, Lane played an instrumental role in establishing the NNI during his tenure as science adviser to President Clinton.

Smalley, the Gene and Norman Hackerman Professor of Chemistry and professor of physics at Rice, is one of the world's leading authorities on nanomaterials. Smalley won a share of the 1996 Nobel Prize in Chemistry for the discovery of C-60, the form of carbon used to construct nanoscale materials such as fullerenes and carbon nanotubes.

FRONTLINE NANOTECH REVOLUTIONARIES
TELL HOW THEY'RE CHANGING THE WORLD
By Candace Stuart
Small Times Senior Writer

HOUSTON – Picture this: President Clinton and Chinese President Jiang Zemin huddled in conversation, discovering a shared passion the emerging field of nanotechnology.

Neal Lane, Clinton's former science and technology assistant and now a professor at Rice University, offered that snapshot Thursday as he described how top-level support spurred efforts such as the National Nanotechnology Initiative (NNI) launched under Clinton.

“The world is changing,” Lane told a capacity crowd at an NNI Regional Symposium on Rice’s campus in Houston. The daylong event was designed to bridge divides between the research, government and business communities using their common interest in nanotechnology.

Like Clinton and Jiang, their enthusiasm about the future of nanotechnology overshadowed institutional differences. And like Lane, most agreed nanotechnology was changing the world.

“I believe that this (nanotechnology) is America’s future, the world’s future, but particularly America’s,” said Phillip Bond, undersecretary of commerce, adding that the Commerce Department has made it a priority to increase industrial commercialization of nanotechnology by helping move discoveries from the lab to the marketplace.

To be successful, the nation needs sustained federal investment in research efforts and informed public policy makers who would stick with the cause over time, said Bond, who served as director of public policy for Hewlett-Packard. He predicted nanotechnology would offer incremental changes in the near term but significant leaps in the long run.

In the meantime, he advocated a strategy of “hope and hype” – hope to carry nanotechnology from the discovery stage to commercialization and hype to keep a buzz among decision makers and the public.

Richard Smalley, a Nobel Prize-winning chemistry and physics professor at Rice whose co-discovery of fullerenes helped open the door for nanotechnology, said the field has matured from interesting science to useful technology. Fullerenes are all-carbon molecules that can be used as nanoscale building blocks in devices or as extraordinarily strong and flexible materials.

“The science has graduated from high school,” he said. “Now it’s time to apply it.”

The symposium was divided into four sessions focusing on applications for energy, molecular electronics, life sciences and aerospace and materials. Speakers included representatives from universities and research institutions, industry, investing and federal agencies.

Energy

Scientists at Department of Energy labs are reaching levels of control with nanoscale layered structures, nanocomposites and nanocrystals that will allow for advances such as stronger magnets for more efficient motors, according to Altaf Carim, program manager of the DOE's materials science and engineering division.

But to successfully find applications, developers must consider how to manufacture devices, integrate them into a larger-scale system and ensure performance and stability, said Terry Michalske, director of the Center for Integrated Nanotechnologies at Sandia National Laboratories. "We have to understand how to couple it to the rest of the world," he said. … "We need to design systems that take advantage of the strengths and aren't defeated by the weaknesses."

Offering industrial perspectives, Dow Chemical researcher Chris Christenson emphasized the need for affordable and well-performing nanomaterials to attract large-volume customers such as Ford Motor Co. Lewis Norman, a research manager at Halliburton Energy Services, added that nanotechnology could potentially monitor deep-sea oil rigs and catalytically break down "sticky" oil products. But he said the 0.15 percent of revenues earmarked by the energy industry for research handicapped their efforts.

Molecular electronics

Molecular electronics offers a "killer platform" but no killer app, according to Brosl Hasslacher, a theoretical physicist at Los Alamos National Laboratory. He along with James Tour, a fellow panelist and a chemistry professor at Rice, helped found the startup Molecular Electronics Corp.

"What you can do with this stuff is enormous," Hasslacher said, but he cautioned that wiring and production were among several problems that needed working out on the nanoscale.

Getting a molecular device to work in real-world conditions remains a concern for Motorola Inc., said Herb Goronkin, director of the Physical Science Research Laboratories at Motorola Labs. While he supports the notion of hope and hype, he added reality to the list, using his lab's ability to grow carbon nanotubes between two contacts as an example. Motorola hopes to use the nanotubes in sensors and for molecular electronics. Motorola is showing success making tubes but is having difficulties measuring their properties.

"These are great technologies, and a lot of work," Goronkin said. "It's important to stay intoxicated with the concepts, and stay sober with the reality."

Life sciences

Morteza Naghavi, co-director of a research center in the Texas Heart Institute at the University of Texas in Houston, discussed the use of nanoparticles and nanoprobe techniques to identify where plaque is building to dangerous levels in arteries. Plaque buildup in arteries can get inflamed and rupture, leading to clots. In another use of nanoscale materials, M.D. Anderson Cancer Center Professor Michael Rosenblum explained how fullerenes are being developed to carry drugs and radioactive molecules to blood vessels that supply cancer cells.

Edward Monachino, an assistant director for technology at the National Cancer Institute, encouraged researchers to consider how they hope to develop their innovations and define their goals at the beginning of their research project. The institute offers a commercialization assistance program to accelerate lab-based research into business.

Aerospace and materials

Chester Kennedy of Lockheed Martin Corp. and John Belk of Boeing spelled out the problems and Bob Gower of Carbon Nanotechnologies Inc. (CNI) offered a solution. Lockheed Martin and Boeing design and manufacture military and space products that withstand the heat and pressure at launch, cold in the sky or space, vibrations, corrosive environments in the sea – and still remain functional.

"Anytime in a place that is really hostile, we're there," said Belk, a technology expert at Boeing. "That's our environment."

Their industry needs to balance the hope and hype, Kennedy said, to ensure their military and commercial products stay reliable for long periods. Nanotechnology offers great promise, he said, but it will be incorporated into products slowly and carefully.

"All the problems we're trying to solve – and nanotechnology says we have the solutions – we have to do it with caution. That's why there's a lag."

Gower, chief executive of CNI, countered that his company's single-wall carbon nanotubes were "ideal for aerospace" when incorporated into composites. The composites offer the potential of being much stronger and lighter than conventional material. Efforts to use them have been slowed by a limited supply of nanotubes coupled with problems dispersing the tubes in the composite materials. CNI recently launched its pilot plant and produced its first pound of carbon nanotubes last week, Gower said. Dispersion remains "challenging," he said, but not insurmountable.

The symposium was the second for four regional workshops supported by the National Nanotechnology Initiative. The Rice Alliance for Technology and Entrepreneurship, the Center for Nanoscale Science and Technology and the James A. Baker III Institute for Public Policy hosted the event.

KUHF 88.7FM
HOUSTON PUBLIC RADIO

KUHF News
May 24, 2002

Scientific researchers, industry executives, financial investors, and government officials gathered at Rice University to look at the latest findings on nanotechnology. U. S. Under Secretary of Commerce for Technology Phil Bond says the Clinton and Bush administrations have shown their interest with research funds.

"We want to make very clear the Bush administration's support for the National Nanotechnology Initiative to get some folks together, stakeholders in nanotech, to talk about the future and commercialization processes and so forth, all designed to keep America leading in the technological revolution. Whether it is national security, homeland security, or economic security, in all three the common denominator and absolutely mission critical is technology."

Rice chemistry professor and Nobel laureate Richard Smalley says it has been quite an accomplishment to get scientists to embrace nanotechnology.

"One of the most difficult nuts to crack here is the ivory tower of science. They went into the field to be seekers for wisdom and truth and beauty, and not to develop technologies, not to get rich, and they didn't like the term 'nanotechnology.' Since the National Nanotechnology Initiative, there has been a transformation, because it is not just a labeling; they really have seen that they are actually close to being able to have an effect on things that people care about."

Commerce Under Secretary for Technology Phil Bond says government has been endorsing fundamental scientific research by setting the right atmosphere for innovators to continue pushing the envelope.

"Even in this wartime budget, as a technology voice in the administration, I am especially proud that we have a record $112 billion in federal R&D in the 2003 budget. Past war efforts have seen huge cuts in discretionary spending by the federal government to shift resources to the war, and so to have an increase in federal R&D in a wartime budget is a big deal."

Dr. Smalley explains that nanotechnology could affect the way medicines are developed for cancer and other diseases.

"In fact, I have cancer, a systemic form of leukemia. In my worst days, I have had about 5 x 10^{11} cancer cells circulating around my body, but because of the major invests in the NIH, monoclonal antibodies, that are actually part mouse, part human, that are approved by the FDA, were used in my case, and really knocked it back incredibly. So I'm in deep remission. The cure to cancer, when it is found, must be a nanometer-scale thing. You cannot cut it out of my body, you can't radiate it away, you've got to put something in my veins which is small, it has to be nano, because it has to be able to move around by its random jiggling, and have a good chance of coming up and nestling against the surface of each and every cell in my body."

Besides nanotechnology's use in medicine, the Rice workshop highlighted its possible role in molecular electronics, aerospace and materials science, and the energy and petrochemical fields. Ed Mayberry, KUHF News.

Houston Chronicle

FRIDAY, MAY 24, 2002

Big boost for ultra-small research

Official endorses nanotech

By ERIC BERGER

The science of the ultra-small took another step Thursday on its journey from sci-fi novelty to industrial workhorse.

A Bush administration official endorsed the still nascent science of nanotechnology during a conference Thursday at Rice University, calling it a key cog to maintain the nation's technological supremacy.

“I'm a believer," said Phillip J. Bond, the Commerce Department's undersecretary for technology. "This is America's future."

In his proposed budget for 2003, Bush increases federal funding for nanotechnology research from $ 604 million to $ 710 million, a 17 percent increase at a time when non-defense domestic spending is rising only a few percentage points.

And, as recently as 1998, the U.S. government spent less than $ 200 million on nanotechnology research.

It's part of the National Nanotechnology Initiative, begun by President Clinton in 2000 and supported by Bush. The research into the realm of single atoms, with the goal of building new materials atom-by-atom, enjoys widespread bipartisan support, Bond said.

The U.S. interest in nanotechnology has been spurred, in part, by recent announcements from the Japanese government that it may spend as much as $ 2 billion on research annually by 2005.

At the conference Thursday, dozens of chemists, physicists and engineers discussed how to move nanotech research from labs into industry.

While there is, as yet, no widely commercial application for the technology, it may well revolutionize the properties of plastics, oils and textiles, giving them breathability, heat-resistance, strength and flexibility.

It also may have wide application in medical science, giving doctors tiny mechanized tools that could zap cancer cells or other maladies. The basic processes of life are conducted at the atomic scale, so it is natural to build solutions to these problems on the same scale, scientists say.

"This is the art and science of building stuff that does stuff," said Rice professor Richard Smalley, a pioneer who won a Nobel Prize for his work in the field. "It is the ultimate playground."

Rice is one of six federally funded, university-based nanotech research centers in the United States.

One topic of discussion Thursday was a molecular computer - much smaller, cheaper, faster and requiring far less electricity than traditional, silicon-based processors.

Although still years from reality, the concept of building a product from the ground up is far removed from traditional methods.

Instead of building something from the top down, say a table by chopping down a tree and fashioning the wood, or building a silicon computer wafer by chipping away at it, a molecular computer would be built particle-by-particle, said Rice University professor Jim Tour.

"That's how nature builds things," he said. "From the bottom up."

Thursday, May 23, 2002
Morning Newscast

Jose Griñan: I've got a question for you: have you ever heard of nanotechnology?

Taslin Alfonzo: Or, why it's important to scientists performing research here in Houston?

J.G.: Well, here to enlighten us is Wade Adams, the director for Nanoscale Science and Technology at Rice University. Good morning, Mr. Adams.

Wade Adams: Good morning.

J.G.: Now, give us the basics of nanotechnology. What exactly does it mean?

W.A.: Well, nanotechnology is the ability to see, to manipulate, and to build things at the atomic or molecular level. A nanometer is a billionth of meter, so scientists are working with the very smallest levels of structure that we can see, and that's atoms. A nanometer is one 50,000th the size of a human hair.

T.A.: I guess that's the simplest way to explain it. Now, there's a workshop today over at Rice University; what will that workshop focus on?

W.A.: It's focusing on how to commercialize nanotechnology. There will be approximately 400 people assembled at Rice from academia, from industry, and from government to talk about the technologies themselves, and how to get them into the factories, and to make new things with new properties and take advantage of the new discoveries in nanotechnology that are happening

J.G.: Now, some of those discoveries involve stronger, lighter materials, industrial processes that pollute less, new forms of medical testing and treatments, and smaller, faster computers. Now, here in the Houston area, we've had several companies utilize research at Rice, haven't we?

W.A.: Oh, absolutely. In fact, Rice has spun off four new companies in the last couple of years in nanotechnology, and we see probably four more spinning off in the next year or year and a half.

J.G.: So what does this mean to the economy?

W.A.: Well, potentially, nanotechnology worldwide is going to produce about a trillion dollars of new business over the next decade. So, it's potentially a huge change in industry and productivity. Houston is well poised to be one of the top four areas, if not the top area in the country, if we move out smartly and invest wisely.

J.G.: Well, it's nice to see that Rice is at the forefront of this particular type of development in technology. Thank you so very much, Mr. Adams, for joining us.

T.A.: Thank you.

W.A.: Thank you for inviting me.

TRANSCRIPTS OF AUDIOTAPES OF BREAKOUT SESSIONS

Session I: Energy/Petrochemicals

Moderator: Dr. Paul Barbara

Legend:
UM = unidentified male
UF = unidentified female

[start of tape, side A]
[recording device is activated]

Paul Barbara:	A few people have to leave promptly at the end of the session or just before so I think we should get started. I've read the four questions that we were given; there are some interesting questions but I'm sure that other people have questions as well. So maybe we should address these four; some of them are relatively straightforward. The first one is carbon nano tubes for hydrogen storage—real or hype? Well, okay, now…
UM2:	[in audience] Hype.
P. B.:	[laughs] Any other opinions? By the way, the people in the front know no more about some of these issues than you do too, so this really is a workshop and we probably should be in a circle than in the front. So would anyone like to address that issue at all?
UM2:	Can I tell you why it's hype?
P. B.:	Yes.
UM2:	Because I looked into that [unintelligible due to distance]. We were very interested in that because we were very interested in hydrogen storage. So, as soon as these reports came in about the possibility of nano tubes as storage, we had a careful look at the results that were in the various publications, in *Nature* and some others elsewhere. It turns out there are two things. First of all the experimentation is not very good, and when you look at it carefully you will discover that, in fact, the results do not fit the conclusions, which is always a bit perplexing. The second thing is that carbon itself…absorbed hydrogen to a degree. If you use activated carbon or any other form of carbon with a high surface area, it will absorb hydrogen if you extend the surface by using what used to be called in the old days activated carbon—you can absorb hydrogen. The absorption of the hydrogen by the carbon nanotubes was exactly the same as that of any other form of activated carbon. So, are the carbon nano tubes something special about

absorbing hydrogen? No. And if anybody thinks differently then they're going to have to do a lot of much more careful experimentation to convince those of us who have looked into it.

P. B.: There is one advantage in that they are nano tubes. [laughter]

UM2: If I call activated carbon nano carbon does that make you feel any better? [laughter]

UM4: Is there more surface there that might absorb more?

UM2: Yes, the question was, because there is a lot of surface area is that going to absorb more? In that sense, yes, but the total amount of surface doesn't appear to be that much greater than other forms of activated carbon. You have to realize that—and this is true of all of these experiments—that the starting material was not as good as is now available. So it's quite possible the experiment should be done again because the orginal stuff, as you know, was published about a couple a years ago. What they had was a mass of material which did contain some carbon nano tubes; exactly how many depends on who you believe. So the starting material was not good enough to be quite as categorical as I was about it. But let's say at this point, the experiments that are being reported do not justify the claim that nano tubes are particularly good for hydrogen absorption.

P. B.: Just to change the subject totally, I'd love to find out who wrote this and they can ask you themselves. Your industry is rich. Why should government give you a dime? [laughter]

UM2: We are constrained as many other industries are…but, in particular, the electricity business has moved very much toward a commodity business. The amount we can actually charge you for your electricity is producing, at the moment, an extremely narrow profit margin. The industry is rich in the sense that the total capital locked up in the equipment that we have is a very large amount of money; however, at the moment, it's very difficult for us to fund the necessary repairs and development, which is causing us a lot of trouble at this time. So, we don't have a great deal of money. On the other hand, should the government pay us money to do this kind of work? Well, quite possibly not. But if the government or the society—just a small point about this—we always talk about THE government, meaning that lot over here. WE are the government. Essentially what the government does is reflect the will of the people—that's us, folks. And they, my friends in government, are pretty sensitive to try to judge what goes on. And I'm not saying they get it right, by the way, but the fact is, it is a public thing.

John Stringer: Well, I think the mission of private industry is to return the value of money to the shareholders; it's not necessarily to advance science and engineering, it's to make a buck and give it back to the folks that own the stock in the company. So, I think the buzz word I like in terms of advancing technology is 'pre-competitive.' At the stage where it's early to make money it becomes less and less obvious to private industry why they should participate, because you don't know how you're going to make a buck with it. So in the quick turnaround American system of non-twenty-five year plans in order to have a policy. We've got five year plans and we change them every six months; that's how we run our business because we've got to make money and make it right now. So at the pre-competitive stage, if it's the best for our country for that technology to reside in our country, and it darned well is and for a lot of stuff we've heard today, if not everything we've heard today, then somewhere, someone needs to come up and raise the level of the playing field and not expect private industry to give us all that money.

UM5: If I can just ask a question about that from a non-industrial perspective? It strikes me that high technology is an area where a tremendous amount of value is added by research and development, where most of everything in the cost of the product ultimately is research and development. But we've been seeing high technology become a commodity overnight. PCs are now commodities. It strikes me that when something becomes a commodity then the profit margins become so small and the research becomes so small that high technology is choked by its own efficiency. How do you deal with that? And I guess Dow is a company that has learned to deal with that.

Chris Christianson: You know that it's a commodity when your PC is sold by its designer color instead of the CPU speed.

UM6: [unintelligible] increase, also.

C. C.: I understand but when the differentiating factor is the fact that it has a translucent cover on it, you know it's a commodity. Now the question is…

P. B.: But it strikes me that…how can we possibly have an economy where R&D is done with full government support?

C. C.: Well, if you ask me the question, we spend about a billion dollars a year on research, that's a pretty good amount of money to throw in the pot and I think it's an appropriate amount of money to throw in the pot. But so what does that mean? That means that we look at things and we say, 'We think we could make money by doing research there and defend it long enough with a good patent position to get to return that money.' Some of our work has to be very fundamental because just like the guy from Boeing said, if we don't understand the failure modes, people become very irritated in the chemical industry if we have failures. They become irritated if we have failure in the polyethylene that you bought. They become particularly irritated if we have failure in the production plants that make it. So, understanding fundamentals is very important to us.

UM8: You largely addressed what I was going to say. You say that the mission of a company is to make a buck and give it back to the shareholders. I think that this is only a part of it; the other part is the mission is to make sure that in ten years you still have a company that makes a buck and gives it back to the shareholders. That's, I think, where medium term research helps out in some companies like Dow, 3M, and Dupont. They are thriving because at every point in their history they've always had in the pipeline research that would carry them through the next revolution. And the government was not funding it, this was funded mostly through their own money.

C. C.: I should point out that the country puts out things like the advanced technology programs where they put in a buck and we put in a buck. We have one of those on platelet-based nano composites going into TPOs for automotive, okay? Is that appropriate? Well, the idea was it's a high-risk game; the country wants to make sure that we, as a country, push the edge. They create an incentive to cause us to take a larger risk. We hope it's a good deal for everybody.

P. B.: Here's a very specific energy question. Given the finite amount of non-renewable petrochemical energy sources on Earth, what is the advantage, other than economics and then primarily for big oil, in using nanotechnology to increase the efficiency of gathering oil and burning oil and gas, et cetera? I guess the question is, simply, is there a long-term energy advantage of really getting more of that energy out if it's going to be from a finite source…?

Lewis Norman: The question is just a bit mixed up, but I think the real question is, why should the energy industry chase new technology, period? I don't care what kind of technology it is. I think there are two reasons for it. Close to home, go down in the Gulf of Mexico and if we can stop the bleeding, slow down the bleeding, lower the slope of our decline of our available resources domestically, then we're a more powerful country; we're less vulnerable to foreign influences. So I think there's a near-term at home benefit. You can curse the greed of the petroleum industry all the way back to John D. Rockefeller if you wish. But the world's global energy technology originated in the USA, with exceptions, but not great exceptions. Houston, Texas is certainly the technology oil capital of the world. So is there strength to our country because that's there? Of course there is. Do you want all the knowledge on how to produce the fossil fuels to come from somewhere else? I don't think so. So those are the two reasons why I think that we should push as hard as we can in nanotechnology and everywhere else that makes a stronger and more efficient petroleum industry.

C. C.: Well, the final question of that cluster, because there's one more that deals with the subject from a slightly different perspective, is how do we persuade the energy industry to invest more in R&D for nano? Is it through ATP programs?

L.N.: If I knew the answer to that I'd probably be doing something a lot more important today than being here! So I would pass this to anyone that would like to answer that. The sum of my talk this morning was point one-five percent coming from the private sector in the energy industry. How many industries could survive at that level of spending? The pharmaceutical industry—we're talking about an order of magnitude or two higher. So how do we change that? What would cause that to happen? I think the only reason it's going to happen from the energy sector is we adopt a more long term focus and we don't have that now. And the other thing would be federal tax incentives and things like that, that would allow us to receive a short-term benefit from a long range goal. There are policy issues, too. There are a lot of wells that are leaking gas in the Gulf of Mexico; perhaps they may be dangerous some day. But the cost to complete those wells to make them much less likely to do that is high. There are seven thousand wells out there leaking gas that will be a problem some day. But the industry is not going to spend the money because it doesn't have to. And, so, until the MMS passes a law that says thou shalt do this then it won't happen. And then whenever it is then the operators will spend the money and the technology will rise. So there are a lot of reasons to make it happen.

P. B.: I've got a question for Terry so he doesn't feel lonely and then that's it for these questions. What are the avenues open for small companies to work towards integration of some of the nano ideas to fruition and particularly with the national labs?

Terry Michalske: Well, the national labs have a number of programs that allow and promote interactions with industry and they're all based on the CRDA systems, so CRDAs are sort of a legal definition of how these work. The funding varies all the way from SBIR kinds of things to drug contracts with companies and so there are, really, a lot of opportunities. They are one of the more exciting things at the national labs, as well as promoting incentives for the national lab employees to get out there and do this kind of work. So, most of the labs now have entrepreneurial offices; they have ways for the lab employees to share in some of the commercial benefits of these interactions. I think that's really had a big impact; you have to have interest on both sides in order for these things to work. I think that's been one of the more important developments in the last five years or so, that the labs have really put policies that promote and encourage their staff to get out and engage in these things.

P. B.: Those were several interesting questions. But let's open it up to some other ones.

UM8: Just a follow up to that, how do you find out about the CRDAs?

T. M.: Each of the labs have technology transfer offices, so, go to their websites and you'll find the links to take you directly there; that's the best place to start.

P. B.: Another issue there is that some of the nanotechnology areas, either in energy or, certainly in nanoelectronics, require big tools; they require tools that are even larger than the capitalization of some of the companies that we've heard about today—tools that are ten million dollars and so on. Los Alamos and Sandia, particularly Sandia, have a number of these tools. The universities are beginning to have them and, especially Sandia through its MEMs operation, welcomes partners, isn't that right?

T. M.: Yes, that's right, and as you heard this morning, Altaf Carim's presentation about the nanoscale science and research centers that DOE is establishing are user facilities and they're meant to provide these tools at no cost to the collaborative community. I think that's going to be a tremendous resource for building these partnerships with industry and university and providing access to tool sets that are just phenomenally expensive to invest in. If you are in the business of just trying out a new idea, you wouldn't want to build a fab to do that; this will now provide that kind of access.

P. B.: There's a question back there?

C.C.: Regarding market research and analysis. I come out of an industry on the commerce side so I think I know how market research and analysis is done on the industry side. But in terms of nano products, what coordination is there, if any, and how does market research and analysis get done on the ultimate final demand and configuration of the products that go into the marketplace?

P. B.: I assume that Dow has had to go through that on some of its nano endeavors.

C.C.: You never think a company would have an R&D department. I mean Dow has an R&D department. I can speak for an industry and a representative of that industry. When we're putting together a piece of work and somebody has an idea—and ideas come from wherever they come from—you've got to tell a story and the story has to roughly be—why is this a good deal? Why do we think it works? Why do we think it's going to make money now? Who's going to buy it? What are they going to do with it? How much are they going to pay for it? Were they going to buy three hundred for Boeing airplanes or fifteen million for the US automobile industry; it's not very complicated in that respect. Getting good data to do it—now there's a complicated question, but the basic idea is all wrapped up in—so why does this change the world? And, oh, by the way, so now we've done it, now we've entered the market. Why is Mr. Smith's company, who didn't spend all that money, not going to go clone it and sell it for seventy-five cents on the dollar and run us off the table? So where's the IP? You will get the "where's the IP" question in my company.

P. B.: In the case of a lot of these projects coming out of the university what they're looking is a first investor—sometimes an angel investor and in other cases venture capitalists that are bringing forward, frankly, where those areas where market analysis can't be done, often the venture capitalists are not interested in it. That's been going on a lot, a lot of discussions. This is not a quantifiable, there's no metric, there's no clear way to do it. In other areas like the electronics industry they have Moore's Law, which says they have to be small five years from now. So they believe they have a directive toward the technology and they know their market, their market is their business. So, in some cases, I think that it's technology driven because they already know the markets. Would anyone like to address those issues? There's a question here but anyone want to comment on those issues?

T. M.: The only thing I might add as Mike (Roco) discussed in his presentation at lunch time there are a number of these regional business alliances that are developing and I have to say I don't really understand the role that they're likely to play; but one would suspect that that's going to be, or part of their function is, to provide, at least in a regional sense, some backgrounds of help in understanding the markets and developing them.

P. B.: Well, in the case where the states have brought money in then what that has meant is that eighty cents on the dollar comes from the state and then companies really can come into this with some feeling that it's a good investment. And in cases where that hasn't happened I don't know what the regional organizations are doing. We have a very active and a very positive thing in Texas, the Texas Nanotechnology Initiative, which is driving this forward. But I'm not aware that they have been able to bring to bear in a broad sense for many companies, you know, funding for this that would be independent of the normal process.

UM10: Along the lines that Louis was talking about as far as commercialization, it strikes me that cycle time is a big, big deal. You've got three factors driving industry—it's initial investment, the terms, and a set time; the guy from Monroe was talking about ten years. And they already had the product and it worked, it's just convincing people to use it. And then the timelines they put up with nanotechnology, it's sort of the same story, whereas we're looking at five, ten, fifteen years. Well, that timeline, that factor is not very conducive for commercialization.

P. B.: That's not on very many companies' radar, ten years, fifteen years; it's off everyone's radar. No one's making investments for fifteen years here.

UM10: [unintelligible] making money off it in a tight time frame if you do an ROI, and I'm just wondering, is there something there that we can really impact on a more fundamental basis. Even getting to failure, if I can get there quickly, is not near as bad as bleeding for five years. I don't know the answer to that but I think it would be very interesting to have some type of forum to share both the successes and, more importantly, the failures so that we can get on with it.

P. B.: When we had a forum like this, not as large as this, but a venture capitalist made these points and then we said to him, "What about the dot-coms?" Because in many cases, there was no profit model at all. And he answered, "Well, an analysis since the beginning of the gold rush and electricity and so on has shown that you only get one of them per generation."

C. C.: It's a learning thing. [laughter]

Mary Bass: I work for an oil company. Are there any major companies in the oil industry who are looking at using nanotechnology in exploration for oil, pipelines, et cetera? Because we do tend to follow suit. When we see the Exxons and the Shells we get on board. And how will geologists and geophysicists that I work with use that as tools to look for oil, to extract it, and the whole upstream, downstream technology? Any specific suggestions? Any majors who are on board already?

J.S.: Perhaps what any of the central core research groups are doing, whether it be the service industry or the major oil companies, at some point in time that becomes invisible to only the insiders. So, yes there is research going on at Exxon-Mobile, Shell, Chevron, Texaco, and British Petroleum and Total/Fina/Elf. So, exactly what they're doing, I don't know, I don't know who that is. I would be very shocked, in some dimension, some place, some spot on this huge surface of nano technology, of course they're doing things. Now, there may be a lot of people doing different things. Within our company there are several places where we have ongoing research activity in the area. So, yes, it absolutely is going on out there. I think in the arena, though, of the original question back about the market, you're exactly right, that we all, in every industry, we all seem to wear the same style. It seems like we do that. But as you can start to see a product it gets very easy to tell the story Chris is talking about. But before you can really see that product clearly it gets more and more difficult to define what is the proper market research. And I think one of the driving needs in our industry, and perhaps others that I don't know, is that what is the process as you go further back up the technological food chain in terms of defining the market when you're really talking about defining the underpinning science under which the products can grow out of? And, so, what you're saying at the 3Ms and the Duponts and the Monsantos and even a Halliburton or a Schlumberger is, yes, there's a commitment to say, yes, this a

core area and I will fuel the underpinning science development activity; but there's just no way you can know what products are really going to come out of that. So, how you define the marketplace at that stage? I don't think we can.

UM11: I have a question regarding the driving force for these nanomaterials. I see two things on how to approach the problem and how to solve it. The first one is the problem exists and you provide a solution. That way you get a lot of the venture capitalists or the people who need the product. What I see from this meeting is that we have this perceived magic material and we are looking for a problem, and we can solve the problem with this material. That's probably why, or one reason why, ten to fifteen years we've been looking, and nobody seems to invest in some ways. My question is, do you see it that way, that there is some big money government and let's go catch up?

P. B.: Yes, on the materials side, it's very natural when you have a new type of material or a new set of types of materials, to realize that you have some tune-ability, some variables to turn that you didn't have before. And then you look, as we heard a lot today, for material problems, which are now insoluble. And you explore whether you can do it. But it wouldn't be worthwhile if it were just a new version of the same material. We've heard several examples of that.

C. C.: Well, as I try to do material product research, which is one of the things I do for our company, I try very hard to begin with the idea that I am matchmaking. In the old time sense we hired a matchmaker to get the girls and the boys together. That means I have to understand what the technology does—that's one of the kids—and the other thing is I have to know enough about the market to know what the market cares about, that's the other kid. So let me give you an example. People really like a blend of polypropylene and some kind of elastomer, which is called TPO in the automotive industry, because it's inexpensive and it does a lot of good things for them. Why do they not like it? Well, it's not stiff enough. And as soon as it starts getting stiff, it starts getting brittle—particularly on the low temperature side. So, that means that there is a market opening for something that has the right price—and, remember, the first four properties are price, low cost, cheap, really low cost…okay? And, so, they would like to have a material, which is stiffer so they can make it thinner. Why do they want to make it thinner? Low cost, okay? Which doesn't break when it gets cold in Michigan, which it does several months out of the year. Now it doesn't make much difference down here in Freeport or Houston or maybe even as far north as Austin. But up in Michigan and, worse yet, over in South Dakota, it makes a heck of a lot of difference about seven o'clock in the morning on the Fourteenth of January. So if it breaks and you had your dashboard made out of it in your thirty thousand dollar car you are some kind of irritated; you are never going to buy from that unnamed company again. So, they want it to be tough down to about minus-forty and they want it to survive out there in the Arizona desert. So they want about…oh about a hundred and twenty centigrade…and then they're pretty happy. But they'd like it thin so that they don't have to put too much of it in there. But, remember, if you're going to make it thin that means you gotta flow like crazy through a real thin mold so the viscosity can't get too ugly. So, know the properties, know the properties that are needed, know the price, know what the technology can do.

UM2: My last question, what can you not do with this nanotechnology and what can you do? I guess it's the same question that the original speaker had, ype and real. I'm the one who asked the first question on hydrogen storage of nanomaterials. Now, how many times is the material, the nano material, for hydrogen storage, just because it's a nano carbon, how much of it was carried because it has a nano in front of it or by the reality?

P. B.: I assume that C60 is the most finely divided carbon, but if it were not in a row form, the single walled carbon nanotubes, not C60, are the most finely divided materials made of carbon. And if that's so, it has, by definition, the greatest surface area. Now, why it didn't work could be because of row bundles and so on; but the concept was a very good one. The concept was that it is, by definition, the greatest surface area.

UM11: How do we exploit that type of carrier with non-reproducible data?

P. B.: I think that we should be very careful.

C. C.: We should kill all the ones that aren't right and, by the way, you should expect that there are a lot of them. And you should press on and not worry about it because you should think about the ones where you have a delta in performance need, you have a delta in cost to drive that performance need, and you have a fundamental piece of technology that says that you can get there. And if you do, you're good, if you don't, pull out and go to the next one.

P. B.: But I'm concerned as much as everyone that we're going to end up looking like cold fusion even though we're not. You know, no false claims about performance. There haven't been false claims about performance yet; there have been exaggerated or more optimistic claims about potential. The difference was that cold fusion was inherent in what it actually did. And I think it's okay to have great hopes in potential because some of them will be realized, but will the public fully understand the difference between great hopes that aren't achieved in three years and outright errors, if not fraud?

UM12: I have two questions but the first one goes to Chris, continuing on your example about the polypropylene composite; you've got to have a delta. You know that you're going to have a delta on the property side but you've also got to have a delta to go to convince them to commit R&D spending or development spending, right? And the predetermined delta on the pricing side—it doesn't match what you get after you put the product on the market?

C. C.: You remember Louis' statement about there's a bunch of interesting work that you're not going to see if you're not on the inside? That's a good example, an excellent example. But, eventually, you will know because one of two things will happen: we will introduce this as a product or we won't introduce it as a product; and then you will know. Now, it may take a little while before that all shakes out but eventually you will know.

UM12: Okay, the second question is, can somebody here, or maybe the group, help out on explaining the current status on nano technology applications in the catalyst area for hydrocarbon processing or polyolefin processing? Does anybody have any ideas?

UM2: I think what you mean by nanotechnology…[unintelligible] taking place on a continuing basis and [unintelligible sentences due to distance]…and the object to that was to reduce costs. And in that particular case, they went to a rather stronger substrate of aluminum…[unintelligible sentences]. Now, in a sense, I suppose, that's getting toward nanotechnology; you're reducing the cost of material by making it thinner [unintelligible]. That carries with it, as it happens, an unfortunate consequence. And then also reduce the particle size in order to increase the surface area, the specific surface area, just the same way we talked about before. And that meant that we had to capture the regenerated catalyst and the ways we started getting into the energy recovery turbines ceased to work, and the erosion rates of the recovery turbines increased enormously. [unintelligible sentences] Whenever you talk about catalysts, you're always looking for the smallest particles, particularly with precious metal catalysts, you're always looking at the refinements where, since every good catalyst does this on the surface, you're trying to reduce the total amount of catalyst you have present, and as you do this, you're getting more and more to very thin layers [unintelligible sentence].

Walter Chapman: I'm Walter Chapman here at Rice. I appreciate the last few questions and your comment: what constitutes nanotechnology? There was one question concerning how is nanotechnology used in the petroleum industry? There's a tremendous amount of work in looking at gas hydrates, for example, for flow assurance. Gas hydrates are nanomaterials, they happen to be water-based nanomaterials, not carbon-based, but they're nano materials. In fact, we're doing some research in that area now. There are obviously applications in other industries. There's a tremendous amount of research in catalysis and, of course, these sorts of materials have been used for many, many years in the chemical industry. I guess as an academic, what I see is nano goes in front of everything now. And this is one of the nice things that's developed is that all of a sudden there is a tremendous amount of focus now on molecular mechanisms, molecular understanding of what's going on. So, all research proposals go in saying we are looking at nano, bio, environmental applications right?

UM: It used to be "-e" didn't it?

W. C.: Yes, it used to be "-e," right.

UM2: It's an individual, the individual molecule [unintelligible due to distance]. It doesn't look like a nanomaterial…it would be like describing water as a nanomaterial.

W. C.: But what's interesting is it's actually crystalline material. It's a crystalline material that's formed and, so, it actually has a nanostructure to the material. And, actually there was a study done at Tulane a few years ago…

UM2: [unintelligible due to distance]

P. B.: I did ask this catalysis question to two of my colleagues recently. It turns out that not all of catalysis is nanoscience. For one, the particles are often a lot bigger than nano requires, and often they're molecular. In either case, in my definition of nano science they exist. But it turns out there are two new things happening—probably many more than two—but two that are very nano: one is an appreciation that no one was considering how the electronic structure was tuning for spatial confinement issues with respect to the catalyst and it's a new concept to go look back and see if there were some nano confinement effects that people hadn't considered; so it's a new idea. Two, there are some new catalysts which work simply because they're nanoparticles of metals, totally new gold catalysts, gold particles that are working as excellent catalysts under certain conditions, revolutionary. So, sometimes new ideas do change an area and I think there's a lot more science to it. You can discover what's nano, here's a way: submit it as a nano exploratory research grant or a NIRT grant and try to put nano in front of it when the community doesn't really consider it to be intrinsically nano and you'll discover the hard way that it isn't. We could all say nano is our definition of nano but, unfortunately, for a while in terms of research support, nano is going to be what the peer review system considers it to be.

W. C.: Wait a minute, a zeolyte is not a nano material?

P. B.: A zeolyte is a nano material in some sense but not…

W. C.: Because the phase behavior is affected, of fluids.

C. C.: The standard zeolytes were under a nanometer in their whole cycle, most of them. But now, there are catalysts like the one that Dennis [unintelligible] had for hydrogenating polystyrenes…which had to have four sizes in the nanometer region, not the angstrom region, because otherwise, the 300,000 molecular weight polystyrene wasn't going to get in and wasn't going to get out. So, now, I would have said to you that that kind of catalyst for a rather large molecule was a nano problem, whereas a zeolyte catalyst [unintelligible] an aromatic chain...

P. B.: You said a nano problem and I think that's the key…you said a nano material…

[recording abruptly ends]

[end of tape, side A]

[side B is blank]

Session II: Molecular Electronics

Moderator: Dr. Harold Hosack

Legend:
UM = unidentified male
UF = unidentified female

[start of tape, side A]
[recording device is activated]

Harold Hosack: Okay, why don't we go ahead? You see me holding this microphone and not making a whole lot of noise probably at your end. The fact is, it's not supposed to. This microphone is only recording into the system. So if you can't hear just put up your hand or something and we'll try to talk louder. I think it will all be okay. This is the breakout session for the molecular electronics activity. And there are two purposes here: one is to provide answers to questions that you might have from the panel. And the second purpose is to try to get your feedback on how this has gone and what NNI can do to make these sorts of activities more useful to you and what kind of things that you might like to see in other meetings. We have three of our four panel members here: Dan Leff, you remember, he is the one who spoke about some of the financial aspects of molecular electronics—the kinds of things that can be done there. Herb Goronkin, from Motorola, who talked about some of the industrial sorts of activities. And Jim Tour who's from Rice; he talked about some of the other technical sorts of things. Brosl Hasslacher had to leave so he will not be here. So let me just start out and open the floor and see if there are some questions that people would like to ask the panel members. You're all here so I assume that you would have lots of questions for the panel…okay…since I don't here any immediate questions, it turns out that I have—ah, yes, please?

UF1: [in audience, low audibility] Actually, Daniel, I have a question for you. Um, [unintelligible] brought up a lot of reservations about technology and caution about what we ought to be looking into. As a venture capitalist, how do you do that? And are you looking at things in the way that [unintelligible] at this point looking at technology?

H. H.: [distant] Talk into that…repeat the question…[unintelligible]?

Daniel Leff: I was going to say, I think Brosl had some fairly negative things to say about venture capitalists, but even then I think Brosl had certainly less sobering views than Jim or Herb. I thought Jim mentioned in his talk, this is what we're working on and, timeline and commercialization is many years out. But, you know, from our perspective, I think that certain areas of nano science have evolved rapidly over the last several years. And it makes sense for an early stage venture capital firm to at least do a few and select kinds of investments in nano technology in general. I mean, we look in all areas. Jim had asked me to come and speak today specifically about nano electronics but I'm very interested in things at the interface of silicon and life sciences—things like next generation nano fluidics gene chip—bio chip-type technologies. I'm also very interested in chemical sensor technologies. We have a number of photonics investments in our portfolio, and one of the most recent is what I would call a nano photonic integrated circuit type of investment. So, we're going to continue to make select investments. But I think the key thing to be aware of is to really understand the technology well, understand the time horizon, and again, if it's five years out, that's okay as long as there's a coherent strategy to get you there. And I think a number of deals we're going to do in this area are going to be more like seed-type deals where you put in, let's say, less than a million dollars and you structure the company properly from its inception. And you bring in the management team and you do the market analysis and develop the most appropriate business model and grow the company very slowly and not raise large amounts of money at high valuations. I think that's how we're going to do it.

Jim Tour: Can I comment on this? Because I've been on the other end working with Daniel. And these guys know how to build companies—I don't. I have this great vision of changing the world. And Herb keeps trying to draw me back to reality but it's really hard to put something into somebody's computer and…wouldn't you say that…it's kind of tough to do that isn't it? [laughs]

H. G.: [distant] It's tough to pull you back! [laughs]

J. T.: It's tough to pull me back, right [laughs]. You know what's going to happen—and I didn't say it in there—but, again, I don't know where the press release is…can we announce this that we're kind of…? NEC has started working together, and has a memorandum of understanding with Motorola, where we're making this CMOS with afterburners. I didn't know if you knew that that's what we're calling it. But it's kind of a neat name isn't it? You know, because we're trying to take CMOS transistors and hook on molecules in a certain configuration. Now, are there some hurdles? There are, even for this 1-K demo which we've been saying for a long time that we're going to build. I mean, it's kind of tough because we're going from the small area to the large area. But if we do this it's going to be kind of neat. It's really going to demonstrate something nice. The other thing is interconnects—we have a memorandum of understanding with Amphenol. And interconnects are much simpler than memory. Why wouldn't memory be one of the places we want to go? And memory, if I understand this correctly, took thirteen price cuts in a twelve month period. And the CTO of Micron said that they were selling memory for less than it cost them to make it. I don't know how they could continue very long like that. So, memory might not be the best way to go initially. It might be in displays, as I think we've talked about. So, here's what's going to happen. I'm going around talking about all of the things that we might want to do. But there's a lot of smart people out there that all of a sudden have something else in mind. And this gets back to a book that Herb told me to read about a year and a half ago—*Innovator's Dilemma*. And I read that book and what it says, it's how do you insert a new technology? You probably read this book. How do new technologies insert? They never do a direct frontal assault on the top end, never. I think you'd fail trying to go head on in memory. But where they come in is at a base level where there's not a whole lot of action occurring. And then somebody else sees it and says, 'Hey, I can apply that to this. I have a problem over here.' And, just recently, I was contacted by a company that I had gone to a year ago and spoke—it's a Fortune 100 company. And they said, 'Hey, we want to build XYZ and we need your special sauce.' And then they told us what they were trying to build. I said, 'I don't know how you would build your part of it. I can build the molecular part, that's no problem.' They said, 'You don't worry about our part, we've taken care of that.' And they have the mechanisms to take care of that. So they assured me that their part is taken care of. I assured them that I can put the molecules on those particular surfaces that they want to deal with and with reasonable order. And that's all they need. And, so, that's what we need to do. So, for commercialization, I think that one of the things that we're trying to do, which I think is important, is we're trying to look at different partners. And Motorola has a team of about sixteen people, from what Ray told me, working in molecular electronics/nano tubes. And that's a pretty sizeable group of people and with a lot of expertise. And we want to couple with them and work with them on that CMOS with afterburners. There's Amphenol on interconnects, a world wide leader in interconnects—we want to couple with them. And build these strategic partners—people who understand what it takes to put something in the marketplace. And I get the reality check from Herb saying this is going to be a longer haul than you think—and that's good, I need that. But, on the other side of it, then I want to partner with yet this third company because this really is a platform. And what Daniel keeps telling me, from an MEC standpoint, what might be best is to focus, focus, focus—and I don't disagree. But if you have the partner to do the muscle work it might not be a bad way to go, right? But, you know, we're just a few little people in a tiny little company and if we're going to do something and bring it market, Daniel's told me even if it takes eighty or a hundred million dollars, they're prepared to do that if they can see the pathway. Isn't that what you told me, right?

D. L.: Yeah…[laughter]. Well not eighty or a hundred from our firm specifically but, for example, if someone came up with a plan for this. Take a look at these memory companies that have been funded—Nantero, which is a carbon nanotube based approach; ZettaCore, which is this sort of large biomolecule approach to memory; and there are a number of others out there. If there weren't significant questions of technical feasibility by those approaches and they were more engineering challenges and you could scope out exactly what that development path would look like and determine the magnitude of money, and you could actually build what you claim you can build, then you could go and raise that kind of money. I think to build a next generation of memory, it will take at least that magnitude of money. And I think it will take more years than a lot of people think. And the more I talk to people, I should think more in a five to seven year time frame. And now I'm thinking something like a next generation memory based on any of the sort of nanometer scale platforms that I showed today is maybe ten years or beyond that. I think Herb's got a very good perspective on that.

H. G.: Jim and I have another point of departure. Jim thinks this is going to be a memory and I don't think it will be. I think it's going to be an information processing opportunity because I think that when we get the probes done and take a look at it we're going to find that it probably doesn't hold its state very long in Tempe, Arizona, outside, but we will be able to learn some interesting things. This technology is at the opportunity stage and the participation—the fact that we're participating in it—gives us all an opportunity to move it forward quickly.

J. T.: And even on this I don't disagree with Herb. Herb's had so many real big successes. If you've got a Motorola cell phone its got Herb's chip in it. This is what we're dealing with. I think I can make a molecule that's going to hold the memory state for months, but we'll see. But even if it doesn't, do you want to make a processor out of it? Fine! Great! [laughs] That's even better! So wherever the opportunities are I think that's what we want to jump on. I'm not upset that Sevin Rosen hasn't yet funded MEC; I mean, it would be nice if they did but I understand where they're coming from. They need a return on investment in a certain time frame because there's a lot of people's personal dollars in that. And I'm not sure that we're there yet for the types of things that we've targeted—I understand that. But then there's other places out there can take a little bit of a longer term look at this like a Motorola and they can apply some more muscle and some more expertise and can help us along. And this is what I want, to get the word out there. And this is also an academic mission. This is what we're supposed to do in the academy. If we can't incite the students to get up and riot or something, I mean, we have to get the world excited about something. And this is an opportunity and so we want to get others excited about this and say there's a lot out there. We've come up with a few things, look at it. If you can apply it in another venue, God bless you, do it, apply it, and we wish you well.

H. H.: Okay, is there another question or a follow-up question to that? If there's not, let me just push that along a little bit further. You know, the question of where this is going to be applied and what the companies are is really a very interesting one. If you look back in history, things that are a truly radical change in many cases had started out with small companies. And if you look back in the past there are many companies, such as RCA, who are no longer there. You know, if you look back twenty years and say what were the major companies at that time? And say what are the major companies today? There's probably only four or five today that were the major companies back at that time. And a lot of that has been changes that have occurred that some of those large companies were just not able to respond to. So the question that I would ask is, and this is sort of an unfair question maybe because we do have representatives from all sides, is, from your point of view, do you see this as the kind of a change that's going to wind up being in ten years or fifteen years? A lot of companies that we have not seen before who are producing nano electronic devices of some type, or is it going to be the companies that we see now that have maybe learned their lesson or are able to respond better. And I guess I'd like to start out with somebody dealing with the money.

D. L.: Very good question. I think for certain applications, and, specifically, in nano electronics, I think that a small startup company can make a tremendous contribution in a number of ways and has the potential to become a market-leading entity ten years from now—sort of a next Intel. But I think only for certain areas of applications. If you think about what it may take to build a carbon nanotube-based electronic detector—something very simple. Let's say it doesn't even distinguish between a particular analyte but it just detects, yes or no, something is there and can detect something in a very small quantity. Because of the technical challenges associated with that, I think something like that is easier for a startup to bite off and chew in the near term versus building high density, low power non volatile RAM…that symmetrical fast read/write. I think that a Motorola or an Intel or a TI are in a much better position than a startup to still own those types of technologies in the future. So I think there's a whole gamut of opportunity and I think some of them startups today will be the next Intels, Motorolas, et cetera. But I think the Intels, Motorolas, TIs, and HPs are going to do just fine because they have active groups and world class research teams working on these problems.

H. H.: Herb, would you be interested in addressing that sort of from Motorola's standpoint? Will Motorola be around in ten years?

H. G.: The whole key to whether or not Motorola can sustain its activity in this area is staying power and patience because this is a long-term research program and, at least at the moment, we're on a quarter by quarter cycle to make money because we've had a few quarters of losing money. But, still, in Motorola we are receiving continued support, in the area of molecular technology. And I think that's true for a couple of reasons. One of the reasons is that it's perceived that we will need molecular technology to meet future logic and maybe memory—certainly information processing requirements. And we have to participate in the field in order to do it and in order to stake out our intellectual property claim, and to be able to jump on new discoveries as other people make them. The other part of this is we have a research lab that's been reasonably successful in picking projects and sticking with some of them to the point where we have been able to convert them to a manufactureable commercial product that makes money for the company. And, so, that's the reason that creates a comfort level within the upper levels of the organization to continue funding this. Because, after all, even in a company like Motorola or IBM or HP, this is a venture capital situation. The company makes an investment in the technology and hopes for a return on investment. We generally do not keep a project going indefinitely. We stop and start, or start and stop many more projects that we start and finish. So we've killed projects on a fairly regular basis but it's usually infant mortality rather than waiting until the project is mature.

J. T.: I was trained as a synthetic organic chemist to make pharmaceutical products. And what I saw in the Seventies and early Eighties were a bunch of companies called biotech companies and they were doing things that the Mercks and the SmithKlines didn't want to do. Some of those small companies are still around today and they're billion dollar market cap companies. Others of them, when they started doing well and the Mercks started seeing that, they went out and acquired them. Biotech has a tremendously long gestation period; it's not three years. It's not unusual in that area for it to take ten to twelve years to bring in money. Maybe I can get you to follow up on this biotech model because you've got the MBA.

D. L.: I didn't really spend much time in business school although I do have the degree. I spent a lot more time in the lab, Jim, many, many years ago and I think you're right. I think you've pointed out a very unique model and it has worked fairly well for the biotech industry. But it's a very different kind of model to build a company, finance a company, develop products at a company; it's a very different industry. When people think about nano electronics they think about, sort of the next generation of semiconductor products or information processing. I know that some venture firms are thinking about nano electronics as life science type investments, and looking at it sort of as broad technology platforms and having IP licensing as sort of a near term revenue opportunity. But one thing I will say about that is if you look at biotech in some of the business models for the genomics companies it's really interesting what's happening right now. You look at companies like Incyte Pharmaceuticals, Human Genome Sciences, Celera Genomics—they all started, essentially, with an IP licensing model where they license their genomic databases to the GlaxoSmithKlines and the Mercks et cetera; they reached a limited revenue opportunity and now they're having to morph their business models. And almost all of them are becoming drug discovery companies. But along that way they certainly created a lot of value and licensee their intellectual property to the drug companies. So I think some of that will happen in nano electronics but you've got to think about where those licenses go. If you're Motorola or if you're Hewlett Packard or you're IBM or a few others, and you're building up fairly large groups (and I'm interested to get Herb's perspective on this in terms of what Motorola might be willing to license from a Jim Tour at MEC or others) of researchers in this area that are developing their own intellectual property, and if it takes a large number of years for anyone to get a product to market and they're starting as early as the startups are and they have much more extensive resources, and they've got a corporate history of fifty or more years of putting this kind of product into the market, I'd be interested to know if they plan on licensing IP from some of these startups. So it is an interesting model.

H. G.: We would prefer to not license IP from anybody. But sometimes we have to. When we're working in a field in which we generate our own IP and there's another organization that is working in the same field generating their IP then what happens is cross-licensing. When money changes hands, the company that has the bigger stack gets the money. The reason that cross-licensing is important is because neither company can sell product without cross-licensing. So if we're in the same market that's the name of the game.

H. H.: Thank you very much. Any other questions that have come up in your minds during this time?

UM: [in audience, distant] You asked the question about running the NNI for the future…I have some thoughts about that. I've been to a number of nanotech conferences in the first half of the year, I'd say a dozen of them, and they're all, for me, characterized by a group of people either who give a technical or business type of presentation and they have some venture capitalists in every meeting I've been to. They make their comments about what they think the future is but they all seem to back pedal from investments because there aren't any good business models. And I think that comes down to not having any of these so-called killer apps that I think your partner was speaking about. So I feel like if NNI wants to energize this industry, which is full of really sharp and intelligent people with brilliant ideas, there has to be some bringing together of the human capital in doing the research and the science and the physics and the chemistry with some people who have some creative real applications. And what I heard today was a lot of agencies or business people standing up and saying we have a lot of need out there. We haven't got a clue how we're going to solve this and we really don't have a clue how nanotechnology is going to help us. So, in the future for NNI meetings some working level to bring the brilliant ideas together with some killer apps is going to be necessary. I think there's going to be a falling out very quickly of investment in nanotechnology. The other thing that would really be valuable would be the companies who are actually successful; (I don't know if you could get them to come in and do this) have them come in and explain their business models. Companies who have been invested in by venture capitalists, and I'm in my third startup so I know what that's about, talking about net present value, indirect rate of return, ROI, whatever number you want to use, but let's use some real numbers, let's talk about investment up front, let's talk about potential for the future and give some market projections. I have not seen in six months a single presentation that goes in that direction. So I would like to see some more of that because it's hard to believe that nanotechnology is going to go anywhere with the kinds of presentations that I've been hearing in the last six months; that's a perspective, my own personal perspective.

H. H.: So you would look for having workshops but the workshops would be workshops between potential users that had some real things they wanted done and the people who are working in the technology.

UM: Yes, so they can solve the problems, with real numbers and real business plans.

H. H.: Yes, in order to try to define some of those killer applications, assuming there are some. This morning Brosl made the comment that there are no killer applications. I'm not sure everyone here has that same opinion but if you can talk about that as well that would be very good.

J. T.: I think the phrase killer application is a strange one and I don't't know why Brosl used it. There has been venture capital investment in nanotechnology. Yes, the magnitude of it has been extremely small relative to what's been invested in enterprise software, photonics, network infrastructure, wireless infrastructure, things like that. But, a most recent figure I saw, since 1999, about three years, roughly $350 million has been invested in nanotechnology startups; that's not a bad number for such a nascent and emerging field. So in terms of business models or nano electronics addressing a real problem, there's one company that I've spent some time with that is building very simple chemical sensors based on using carbon nano tubes as active device elements. This company has had extensive discussions with companies in the petrochemical industry to solve problems that can't be solved in any other way; in fact, I was very fascinated to hear about this. And one of these problems in particular is that an oil refinery may have something like ten thousand nodes of valves that leak and need to be checked. And there's no cost-effective solution to go and put a sensor at each valve. So, what they're doing is they're on these preventative maintenance schedules of changing out valves—it's extremely expensive. This company has spoken with some petrochemical firms and also with the Honeywells of the world that build complete sensing modules and believe that they can solve this problem. So there's a real world problem. You can make some estimates about what you're going to build, what time frame you think you can build it in, what you can sell it for, and you can call up the petrochemical companies, and you can call up Honeywell and find out what they're going to pay for it. So that's the kind of thinking we're trying to do. There are not a lot of examples like that yet.

UM: We need more of those because that's something real and, unfortunately, we're not doing a lot of that in the conferences on nanotechnology.

J. T.: I don't know why we're not. I think a lot of people want to talk about the magic and the potential promise of nano technology instead of talking about some very near term applications that can be actualized within the next couple of years. But I've seen some others…I've seen some things in terms of using carbon nano tubes as field emitters and companies claiming they're going to have products on the market next year but let's wait and see. But if they do, I think it's a nice early vote of confidence for applying some of these technologies.

H. H.: Any other question that have come up? Okay, I've got several questions here from the audience. One question…

[recording abruptly ends]

[end of tape, side A]

[side B is blank]

Session III: Medicine / Life Sciences

Moderator: Dr. James Murday

Legend:
UM = unidentified male
UF = unidentified female

[start of tape, side A]
[recording device is activated]

James Murday: Okay, while we're waiting to maybe get the last few people in, my understanding is this afternoon we're being taped, audio taped, but there is no visual. The reason for audio taping it is that they have reprieved those of us who are moderators so we don't have to go around and take copious notes. The idea of the audio tape is they can come back later and get this transcribed and then try to extract what wisdom we have to offer, so that's the reason for it. But in order to make sure we go on the tape, there are two microphones—this one, which we can pass around, or come down and use the microphone here in the front of the room. I'm going to be soliciting comments so, I hope the two of us aren't going to be the only ones talking [laughs]. Okay, all right, there…

UM2: [in audience, distant] My question was to [unintelligible]?

J.M.: No, I think the microphone basically is meant to be playing into the tape machine and I think they're counting on the fact that it's a small enough room that we can hear, but that being said if anybody's having trouble hearing, put a hand to your ear and make sure we speak up a little bit. Okay, let me start off with two observations. One is Jim Tour this morning offered an analogy when he was talking about electronics. He talked about using trees, growing trees, sort of a self-assembly process, in which then mankind intervened and we chopped them back down and made them into furniture. And he pointed out that in the semiconductor industry we're starting from this big thing and chopping it down. And he missed an important fact there; actually, these two processes are very similar, because you've got to go back and say where did the silicon come from that we're busy whittling away? And, in fact, that silicon came from a self-assembled process. That's what crystal growth is, atoms self-assembling themselves. So, in both of these systems there are different levels of complexity but we go from a self-assembled process, which nature is dominating, then man is intervening and saying, 'Look, I really wanted to do something else' and then we've been whittling down to try to get that thing that's useful to us. What our challenge is on both the semiconductor side of the house and on the bio side of the house is how do we put direction into that self-assembly? Can the tree grow right into a chair or a table, to use that example, in the same way that you'd might like semiconductors to assemble themselves into some functional circuit? So the two things have a good degree of similarity. Second point I'd like to make is that for all the sessions, you guys have got an interested and very willing victim. I have a major role within the nano initiative. And so the questions that we relayed to you, and the reason for this session this afternoon literally is to bring feedback into the nano initiative so that we can restructure it and make it more effective. Whereas the other sessions are going to go through an audio tape and a transcription I can absolutely guarantee you that everything you say goes right to somebody who's in a position to either ignore it or do something about it. But you can be really uptight if you have good advice and I don't follow up on it. What I'd like to do is start off with some of the questions of those people who did write it down; to ignore them, I think, would be inappropriate. So let's deal with the questions first and then I want to open it up. I want to ask a few questions and I want for you here to start giving me some of your responses to them. Okay, there are two questions that I think are fairly similar so let me read them quickly: one was, with the advent of smart self-assembling materials we must be cautious in disposal and release to the environment. What steps are being taken to ensure those substances will not adversely affect humans or the environment? And another which is somewhat different but has some of the same characteristics to it, is I hope to be the first person treated with a nano drug. I hope to use the mass hysteria that will surround the drug's introduction to win a large lawsuit. How do you prevent this? One of the responses I would have to that is we are highly anxious about making sure that we approach the nano world in a safe fashion and in particular if you get into the biological aspects of it, there are three agencies now that are paying explicit attention to it. The NIH certainly worries about it in their programs all the time. And there are a good deal of quality checks and safety checks that go into the research involved at NIH and I'll let Ed (Monachino) answer that in a little more detail. But, separate from that, the EPA, the Environmental Protection Agency, has brought as part of the nano program an initiative explicitly looking at some of the environmental impact. And then as you all know from being here at Rice, NSF is also paying attention, because there's a Rice center here, which is looking at some of the environmental aspects. So there are at least two federal agencies addressing the environmental piece of it directly. And, perhaps, most importantly from the standpoint of the law suit, that's not unique to nano, it's true for all drugs. And the FDA literally last week has joined into the initiative and is starting their program so we will be processing information associated with drug and human treatment certainly in the same way you would process all other interventions to humans. If there are problems there, then, presumably they will be protected in the same way we presently do it.

Edward Monachino: I guess we don't treat nano any different that we treat anything else. If it's basic fundamental research, you first test to see if the product works as planned and you do that on animals—be it mice or rabbits or whatever. And before it would even be thought of going into a human trial you would have to get it through all of the animal testing. And then you would have to get it through all of the normal FDA loops before it goes through human testing. And, so, I really don't see treatment of nano technology any different than anything else we develop.

J.M.: Yes?

Sivaram Arepalli: This is Sivaram Arepalli from NASA national space center. Ken Cox did say that we had started some work on checking out the toxicity of nano tubes. He didn't complete the story. There is a group called Safety and Reliability Division at NASA; Alice Lee is a group lead for that. She actually a couple of years ago started this program whereby they took some of these nano tubes made by different processes—from the arc process, from the laser process, from the HiPco process; they actually did some tests at the animal level…did some feeding to mice and, of course, they didn't try with humans yet for obvious reasons. What they found that I can share with you right now is that the toxicity of nano tubes is not really that critical but the toxicity of the metals that are involved as part of these nano tubes is critical. Now, for example, they're waiting for nano tubes without all of the metals that we use; then they will do the further testing. So, for example, the cobalt and nickel and iron and so on is a lot more toxic than the nano tubes themselves. Also we had some testing by, I don't remember which [unintelligible]; they actually tested how the nano tubes get dispersed. When we collect the material, for example at NASA we have a laser process where we just make the nano tubes, and one of the technicians has to take it out. And, of course, we do take all of the precautions that we know, lab coats and respirators and so on. That may not be enough for the nano tubes but what we realized is they actually did test how how much of these nano tubes go into air; and, fortunately, it's concluded that they really don't get into the air as much as we thought it would be.

J.M.: Okay, another two sets of questions here that have, again, some similarity so I'll take them in tandem. One here says assuming nanotechnology provides revolutionary solutions to cancer research and treatment, as we improve our ability to handle the disease, then people are going to live longer and there are going to be social consequences to that. Is there a concern here and I'd say I don't think this is generic to nano. One could argue our entire funding at NIH is designed just to do this. Certainly it's a social problem that has to be examined. Within the initiative there's something called social implications. It's not a heavily funded effort, but the reason for it, in any extent, is to begin to look at some of the consequences of what might be happening. Longer life, I think, is not probably the one that would be dominant because that's basically the function of health research all along. A different form of the question which could be more important is what happens if, and let's take an example which wouldn't happen fast but let's say it did, molecular electronics blows out all of silicon and all of the sudden half of California is out of work because Silicon Valley no longer exists and molecular electronics is now functioning down here at Houston. That's an exaggerated example but part of what we're trying to do under the social implications is to look at what are some of the economic consequences that might be coming out of this?

E.M.: I think if I could make a point on two areas regarding the social implications of this, curing diseases; we should all be lucky that we have that kind of problem, okay? And that's really the bottom line there. Hopefully we'll have that problem and we're working hard to see that that comes to fruition. But the second is a comment that I would like to make to the group and that is I hope that we're not going to pour a huge bucket of water on a smoldering interest fire, that we don't try to over regulate this entire process so that it becomes so difficult to do this work where it's already difficult to do it that new researchers don't start working on it or people don't get involved because it's so highly regulated. And you have to understand that we're coming from across the street, in the NCI, we're coming from a world in which we give drugs to cancer patients all the time that have an extremely narrow therapeutic index. Which means that if you give a little bit too much, the patient is killed, or suffers major toxicity. But that's the nature of those kinds of drugs; they're far more dangerous and far more powerful than any of these tubes or Bucky Balls or any of that. And they're pervasive, a lot of them are. So it's really hard for me to get worked up about the toxicity of Bucky Balls and Bucky Tubes when I know, for a fact, that these things are extremely nontoxic in animal studies. And I doubt that we're going to see any environmental problems or even with people that have exposure, as long as we're careful. I'm not saying not be careful, I'm saying let's absolutely be careful because one of the things that we've learned over time is that we thought chemotherapeutic agents were pretty benign in the kinds of concentrations that people were working with. It turns out that pharmacists and nurses and physicians who administer this stuff can get reasonable doses of these drugs in their bloodstreams just by handling it. So that's led to, over time, some guidelines as to how these things are handled. But we're talking about something that's several orders of magnitude more toxic than what we will ever create from Bucky Balls, in my opinion. And I would hate to see us regulate ourselves into a frenzy so that it's difficult to do this kind of work and dampen the fire that people are just starting to catch.

J.M.: At any point if anybody would like to ask a question feel free to raise your hand and jump in. Okay, three other questions. One's from Dr. Naghavi who isn't here now. It is basically the question of how will his new imaging techniques that helped him identify vulnerable plaque reduce risk further? One of the lessons I learned very quickly is two things: one is you could identify earlier with the imaging techniques that the incipient part of the disease and anything you catch sooner of course has value. But the more important thing I got out of that is that the model for how the catastrophic event happened was dramatically changed. And I know whenever you try to fix a problem starting with the wrong premise you end up doing, more often than not, the wrong things. So, already, that new technique seems to have made a very significant contribution and that you're starting to approach it differently—that means the treatment procedures will be very different. Hopefully I didn't put improper words in Naghavi's mouth there. Then there are a couple of questions associated with the venture capital people, who also aren't here. I'm not competent to answer anything there, so I'm going to pass questions. There is one that I would like to open up and see what other people might respond to. It says, 'It seems that the medical side converges academic domains that have traditionally been at odds, i.e., not worked together quite as closely as maybe as desirable in a future role. What incredible combination of degrees would you recommend to a high school student wishing to work in this domain?' That raises an interesting question about educational processes. So rather than my trying to field that, would anybody else like to tackle that question? Especially somebody, because I'm a government weenie, who's in the academic community? [laughs] What I will say, again, that is something we're concerned about and part of the social implication of the vast majority of the funding, is being funded at addressing changes in educational paradigms.

UM5: Well, I'm not really sure what the question is. What degrees give you the skill sets to be able to do what? I'm not sure what it is they want to do. You need engineering in materials. There's no one easy answer that's going to answer this question.

UM6: I think the answer is easy, you want a super animal that has trained and a PhD in biology and computing and sensor technology, bio-engineering, and that will bring it all together!

S.A.: All these years now we have physics or chemistry or business—things like that. What this NNI or whatever is coming out with nano technology, you should not be limited to that. Probably the biological part is very important. A lot of us don't know anything about that especially coming from hard-core physics [unintelligible]. We never looked at biological aspects.

UM5: Well a lot of biologists don't know anything about biology either so…[laughter].

J.M.: Okay, throw the mic back up in the back row there. We've got a couple of comments back there.

UF1: I'd like to add another dimension to it. I have a bachelor's in biochemistry and I just completed my MBA at Rice here so, in order to be able to commercialize and know the managerial aspects of it, you'd also need probably a business degree of some sort to understand the commercialization process also.

UF2: I was struck by the comments this morning about the importance of the manpower that's going to be needed in the application of the industry. I think two million was quoted at one point. Obviously we don't need two million biologists or PhDs or whatever. But I was particularly struck by the importance of letting young people in high school and the beginning of college understand the concept that science is a playground, and that it's not what is happening out in the school community now. I have a son who's finishing high school, is going to be a freshman at the University of Pennsylvania in Engineering. It's very easy that he's going to be pulled away to the interests and the application of economics, policy, et cetera for no good reason other than we don't make it easy for our kids to see the excitement of science. And a perfect example here in Houston, Texas is the Offshore Technology Conference does not want young kids to go there. How do you get a young kid interested in the energy industry other than showing him what kind of technology there really is out there? So I think this is a role for NNI and it doesn't relate to chemistry or physics or anything because we saw today it goes across every discipline.

J.M.: There is a report that was produced by the NNI; it was put together by Jim Batterson who is a NASA employee. He came up and served about a three month fellowship in the NNI and it turns out Jim has been very engaged in his educational system. He's got young kids in school so he's been on the PTAs, he's been on the boards of education there in Virginia. So he took this on, in part because it was a love, and he's produced a report which is now available on the web. For those of you who haven't gone onto www.nano.gov, it's a website where we've tried to collect assets or resources associated with the nano initiative. And I know a number of reports are up there and downloadable. I believe this one is one of them. So if you are serious of what we might be able to do to take nano into education, especially education for K through twelve, that is a topic that we are trying to pay attention to. The other piece of information, and for those of you who may not be aware of it, is that the six centers, including the one here at Rice, that NSF has funded, all have a component in it that is specifically to meet K though twelve education. They have been funded explicitly to address that problem, because we recognize just the points that have been made.

UM6: I'm a physical chemist and I've found some of Ed's comments this morning very interesting about interdisciplinary work. My area is we synthesize nano particles and compatiblize them to put them into polymers. But I've been talking to my biochemistry colleagues trying to convince them that we ought to maybe look at some of these things in biochemical systems. And their response universally was NIH would never fund something from a physical chemist. And I just found your comments very interesting this morning. And of course I'm going to take another run at it when I get back after what you said.

E.M.: If I had a buck for everybody that said NIH would never fund…I'd be a rich guy. But the best way to find out whether they would fund it or not is you call somebody like me who works there and ask me. And what I would usually do is send you to the right office or to the right funding vehicle.

J.M.: Yes, and while I can't back it up with a statistic, I had heard a statement made, I think it's halfway believable, right now NIH is funding half of the chemistry departments. So there is considerable funding coming.

E.M.: Well, I don't know how well known this, is but NSF has a program called IGERT which is for people that are at the doc/post doc level that have been doing stuff for a long time in a particular area that want to get a multidisciplinary training. They have a national grant program called IGERT that allows post docs and docs to get multidisciplinary training. And NIH and NSF got together this summer and said, you know, why can't we push that down to grad students and undergrad students and why can't we push that all the way down to the high school level? And, so, NIH and NSF got together and said, 'good idea' and they're taking this IGERT program and they're extending it down. And I would love to see that become a national program where every college has some multidisciplinary curriculum, from freshman all the way up through post doc. Now it's going to take an enormous cultural change for that to occur but that's my dream. I have a fundamental question if I can?

J.M.: Fire.

E.M.: I put up those two view graphs today that got some interesting comments after I got off the stage about when you looked at that FY '03 budget, by government agency. There are four guys claiming they're doing chem bio sensors and four guys claiming they're doing materials and four guys claiming they're doing fabrication and synthesis. I worked at DARPA for a while and I'm working at NIH now and I'm familiar with DOE and I know there's a lot of similar work going on at all these different government agencies. I guess what I don't get is why NNI is not sitting down and saying, look, we need to have these nano technology efforts; we need to have a nano technology effort in chem/bio, we need to have one in fabrication, we need to have one in materials, we need to have in environmental sensors, we need to have one in life sciences. And why isn't NNI saying, okay, the chem/bio work ought to be done by the military folk and the environmental sensor stuff ought to be done by the DOE folk and the life science stuff ought to be done by NIH. I mean, why isn't there some kind of overall coordinated effort that says here's the focus areas and here the agencies best to handle them and then we all go off and do our own thing? I mean, right now, I don't know what the life sciences piece of NNI is and who's doing it. And, so, I guess I'm looking for this over arching NNI group to show me what the focuses are and show me who's doing the work and show me what the coordinated plan is, instead of somebody calling up NIH and saying who's doing nano over there? And we pick the four or five programs in NIH that are doing nano.

J.M.: That's a very good question. For probably most people in the world, including me, the way the NNI appears, it is like a monolithic program; it sounds like somebody has charge of $700 million in '03 and is parceling that money out. In truth, the way the process happens is that the research dollars are coming into each of the agency budgets and it is coordinated at the NNI level. So there is no one budget. In fact, if you look at the federal budget, if you tried to find $700 million for NNI in the federal budget you wouldn't find it. If you look for nano technology in the federal budget you'd probably be able to identify, at most, $100 million. The other $600 million is buried in budget lines throughout all these various agencies. So there is no way to go in and accomplish, by fiat, the point you just made—to tell people this is what you ought to be doing, this is your niche, you're funding it, here's the money to do it. Now, the way we've chosen to handle the reality of the world, which is, NIH has got its money, DOD, which I work for, has its money, DOE has its money, is to go in and look at the areas where we think nano will have some significant impact, from a mission point of view. So there is something we call the grand challenges and those grand challenges generally are fairly closely related to various agencies. There's a grand challenge in energy—DOE is the point. There's a grand challenge in medicine therapeutics—NIH is the point. There's a grand challenge in nano electronics, opto electronics—DOD is the point, mainly because DOD traditionally has been the principal funding of that particular technology. The goal there was not to say that one agency was going to now be the only one person doing that work, but that they would be responsible for developing an investment strategy. Now, do we have investment strategies for the grand challenges? The answer is, only at a very crude level from this point. What is happening now is we've taken on the nano electronics, which DOD is lead, and we are developing that investment strategy. So there are a number of studies going on incorporating the SRC in industry; incorporating the various government agencies, and DARPA is probably an important one within the DOD, incorporating DOE, which also has work going on in electronics, and some in NSF, trying to devise what is an appropriate investment that ought to be made. And then from that to go in and have different groups step up and say, all right, we're going to take the lead on this particular activity, and to minimize any duplication that may not be healthy. I think people would agree with me but I will make the assertion that to some extent you want some duplication, not really duplication but you want more than one approach to any given problem. I would be very nervous, frankly, if someone were to come up to me and say, all right Murday, I want to hand Mike Roco $700 million and have Mike tell different groups what they ought to be doing with it, because no one person is smart enough to span the functions we're talking about. So that would be equally wrong as just throwing money out and having everybody work without any coordination, and to potentially fund things that were truly duplicitous. We have to find something in between. So the attempt at getting these investment strategies is an important goal for the NNI. And if I just heard you (Monachino) volunteer to help to lead an effort in NIH, that is in therapeutics, that would be a very important thing to do. Simultaneously, there's a new grand challenge in the chemical, biological, radiological, explosive detection and protection—homeland defense if you will. There is a study going on now, and, again, I'm at the point for that, that is trying to develop a strategy which says here's where nano is most likely to make an impact, here are the fundamental weaknesses, here are the groups that are putting dollars in. And I would think of all the various areas that's the one where we need to be most concerned about people really knowing what each other are doing because everybody wants to step up and help solve that problem, literally every agency. So there it's very important to make sure that people know what each other are doing; that's one of the reasons we're working with that grand challenge again—trying to make sure we have this investment strategy. So to give you some examples there, for instance, it's very likely the FAA will soon take control of, or the responsibility for, funding work in explosives detection—they seem to have a real interest in that for some reason! Whereas for chemical and biological agents, DOD will probably take the lead because, traditionally, NIH hasn't really wanted to step up to the man-made intervention, they certainly have been worried about what nature does but haven't been so concerned or wanted to get involved with human intervention by way of terrorists. But, that being said, we clearly have to keep NIH in the loop because, other than the fact that you can't really say nature is a terrorist, terrorism is a conscious decision. But I would argue that leaving that nicety aside, nature is the world's worst terrorist and it's killed far more of us than has bubonic plague, or smallpox. This is nature inflicting terror on man and that is within the purview of what NIH does. So we clearly have to keep close connection to what's going on at NIH as we address these various issues.

E.M.: Thanks. There's always this tension between letting many flowers bloom and having programmatic direction put on various processes. I think if we've learned anything from the Human Genome Project is was good to have a phase of letting many flowers bloom but it was also very good to have a phase where there was very directed, very focused programmatic administration of the whole process. And maybe the question is whether that is appropriate here, whether it's already been addressed for this initiative or whether there's something lacking. So I think that's what the question is about.

J.M.: Thanks. Let me broaden that, similar to the discussion that we just have been having, to frame it in the context of one of the questions that we'd hoped to have explored. I want to turn things around now explicitly and have people respond to it from the audience. What changes, if any, in the administrative organization of NNI are needed? How can the NNI be more effective in leading the nation's technology revolution? So, actually, we've had a couple of questions along that line. We've talked a little bit about education. We've talked a little bit about getting a better focus on how the funding are being spent. What other points, what other ideas?

UM10: Just to briefly give the student perspective; I'm probably the youngest person here in the room, being an undergraduate, but in terms of the education question…unfortunately the lady left, whose son is at U Penn, but he should be at Rice, because here, you can be in a research lab. And I know many undergraduates that actually work for Dr. Smalley's group and do get to participate in his research and get on the frontier of nanotechnology. And in terms of education it's by coming to things like this in terms of the young people and learning from many of you who are experts. And just reading basic publications that are coming out and just enjoying the passion that many of the guys that are researching have and knowing that whenever I'm old, I'll maybe get to benefit from some of these technologies that are coming out and just keep a sharp eye on the research coming out and seeing how to become a leader and to take initiative. I started a company that I sold, fortunately, two years ago, a dot-com with a friend at Stanford and it's helping pay for my tuition here at Rice. Taking an initiative like that and stepping up to the plate and learning as much as you can—I think the education is there as long as the recipients are willing, are interested in taking advantage of it.

E.M.: You have to understand that you have this cultural problem. You have those of us who are old who have been in the engineering and science world for a long time; we think it's a great place to be. And we can tell all the young guys we want that but they're not going to listen to us. You have these television shows, you have all this newspaper, you have all this stuff where, what's pulling people away from science and engineering right now is the sexiness of the dot-coms and Wall Street. Everybody, all the young kids, wants to make a quick buck really, really quickly, and they all want to retire by the time they're thirty, millionaires. And that's one of the things that's really killing the science and engineering profession: the culture of making the quick buck through the dot-coms and through Wall Street. That's something that you have to turn around and that's something that we can play a part in as a government. But you're fighting that cultural thing. If you can show the promise of nano technology and show that nano technology could grow the way PCs did in the Seventies and the way the biotechs went crazy the Eighties, and then the dot-coms went crazy in the Nineties. If you could tell everybody that the '00s to '10 is going to be the nano decade then you can sell kids.

S.A.: I think to that end, these so-called NSF centers probably should do that more in educating the local regions. They have the responsibility of doing it either in the form of having something like a nano RAM and going to in schools, and so on. I think it is very important to get these kids interested at the lower level. Once they get interested they'll take off.

J.M.: Let me challenge you on that. We have six centers, evidently it will expand to eight next year, since there's a competition for two new centers about nano manufacturing. We've got fifty states—there should be a center in every state. Other opinions?

UM12: What you need is educational centers. It's a different ballgame. An engineering center is great for developing technology but educational centers are good for getting the word out. We have tons of cancer centers all over the country and those cancer centers are split in half; half of them do cancer research on particular cancer types and the other half are there for sick people to go and get treated. So they serve totally different purposes.

UM13: [inaudible in background]

UM14: Well, I think that's an interesting challenge. Your question is should there be one in every state and my response is we have to prioritize our spending; we can't afford one in every state. There has to be a different way of getting the education issues solved than putting NNI money into that. So, the Department of Education has got to get on board to really solve the education challenge; if we're going to educate two million people to be nanoscience literate in a short period of time it can't be done by creating nano centers, there's not enough time to create that many nano centers with that broad an impact.

J.M.: You've heard the word two million. How many people believe the two million? Let me run a challenge.

UM15: If you want two million people in this field then we have to have a strategy of marketing this field. If you just think that no kids are going into this field because they feel that science is totally different than something that's totally new. But people drink Coke, Pepsi because they're going to see it on their TV. So if the NSF just maybe put some of the money in marketing this as an alternative option, then maybe you'd find more kids coming towards this field rather than kids going away from this field.

J.M.: Okay, let me again throw a challenge out to you. Science and math education, K through twelve, has been a problem, it has been a problem through my entire career. The Department of Education hasn't solved it in that time frame, and I can't see the situation now being that much different. Can nano play a role? All right, let me throw out a challenge. What happens if we could get nano electronics or essentially get a virtual reality system where you could make it cheap enough and you could put one for every student or at least one in every classroom. Could you teach science and math at grade school using a virtual reality machine as a mechanism to do it as opposed to trying to go back and train teachers at that level? That is what we have clearly been unable to do in spite of it being the problem now for at least fifty years that I know of. Do-able or not do-able?

E.M.: Like a mini video game or something where you don't need the virtual reality, 3-D headset and all that other stuff. The guy came in with the Boeing commercial today with the fancy music and all the wonderful imagery and stuff. Why can't you have some kind of training class like you give a government person when they first become a government employee that says here's what nano technology is, here's what you need to do to get educated to go into this field, and here's what all the applications are? It could just be a tutorial type thing. [responding to inaudible comment from audience] You could do the educational package now explaining what it is to get people psyched up; you don't need the nano technology itself to do the educational package.

S.A.: And also the schools have, what do you call it? They have TV—they actually watch the TV [unintelligible] and I think that's spike up…or whatever…probably about an hour or two and include ten minutes or fifteen minutes of nano I think you'll get the most benefit out because they are looking forward to the TV hour.

UM16: I'm a father of three children and two of them are in grade school and one's in junior high. I'm heavily involved with the PTA and I'm doing volunteer work for the schools as well. There is a dichotomy of interest, I think in the educational system in K through twelve. One is that each state is under pressure to meet a certain minimum guideline of performance and that's their number one goal. So, you're saying, okay, we want to introduce this new concept, nano technology. Now it's very, very hard to move this big rock that is on top of the teachers right now. And it comes all the way from the US government down to the Texas legislature, down to the school boards, down to the independent school district, down to the principals and the teachers. So, we have to think outside of the box. We have to act as if we are Procter & Gamble and we need to market this to the children in a different mind in the same way Sony markets the Play Station 2 game. If we want to inspire these students and get a real good interest and passion in wanting to learn and to identify with nano…how do you do that? Well, it's easy in branding.

[recording abruptly ends]
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Session IV: Aerospace / Materials Science

Moderator: Dr. Kenneth Cox

Legend:
UM = unidentified male
UF = unidentified female

[start of tape, side A]
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Ken Cox: This is the Aerospace and Materials Science follow along after our session. First of all, Barbara, my understanding is you have an early flight? All right, if you're going to leave at five I'd suggest if you have any comments you want to make, you do so up front. I don't know whether you want to make any reflective comments or not but I think it'd be appropriate if you want to.

Barbara Wilson: Is this being recorded someplace else too? Okay, then we'll use the microphone because I certainly can talk loud enough to have this room hear me. Something that came up in retrospect after some of the other discussions on the aerospace side was I realized probably that the materials that I presented representing the Air Force probably didn't stress the reliability aspect sufficiently. The aspects of both architectural as well as just duplication because of small size and other approaches are really important from the aerospace side—both from the defense side where you can't have to reboot the computer in the middle of a maneuver in a military action; or of course in space where often things have to be up there for years and years and years and you can't tinker with them. So, for various reasons, from the aerospace side I don't think the reliability aspect came through very clearly in the materials that I presented.

K. C.: Let's discuss the process if you don't mind. I'd suggest that we take advantage of the fact that Barbara's not going to be here very long and that we panelists ask each other questions and we'll take whatever questions you have. This may apply to all three of you in the defense sector, and that is, as we look at our war capability there's going to be more and more pilotless activity, how does nano play in that?

B. W.: Uninhabited.

K. C.: Uninhabited, okay, whatever the right word is. But how is that going to play because I would think that you could maybe make some things pretty small and pretty strong. So what are your thoughts?

B. W.: I think from an Air Force perspective they've just finally embraced the uninhabited air vehicle concept coming from the background. It's a tremendous culture change and it, consequently, has taken a long time. But it's now moving into applicability already. I think, I anticipate, that further progress will be much faster. There are all sorts of schemes in terms of, you know, all the way down to the DARPA and dust mote sort of approach of how much you can get on board of something that is so small, so inexpensive, and so ubiquitous that you can put it everywhere? Then the primary challenge at that point is the command and control. If you can, in fact, have thousands and thousands of things either in the air or on the ground or hopping or climbing or whatever else they're doing and talking to each other, how do you, in fact, manage to control all that or to manage all of that information and to control the system? So, then you have to start looking at entirely other sides of the picture, the algorithm side, and the architectural side that enters when you start having the opportunity to do things that you could never do before because they were never small and cheap enough. So I think we actually have a whole other side of the question where a lot of us are focused on the physical aspect of making these things really small and not recognizing high-speed processing and not always recognizing the other side of the picture in terms of them handling the information, handling the communications, and command and control challenges that will come up there.

K. C.: Any other comments in that area? Okay, do any of the panel members want to make a reflective comment before we start asking questions of the group here? All right, let me take the written questions and we've got two of them. If nano helps increase range and nano particles increase explosive fire, will we no longer need fighters? Yes, well…[laughs]. I don't think they're going away.

John Belk: I don't think they are either. What do they provide after that question? Let's see if we can dig a little deeper into it. Let's say you can deliver munitions across the globe. How does that change the need for fighters or UCAVs (uninhabited combat air vehicles)? By the way, UCAV flew…

B. W.: Yes, that's right, that's the first successful flight…

J. B.: That was yesterday morning? I saw a picture of it on the Boeing web site last night. So what happens when we have improvements in explosive potential and drastic increases in fuel range. All of a sudden you can deliver in a small package and they're really nasty anywhere on the planet. How does that change your world? I'm just rephrasing the question.

B. W.: Thank you so much. I think there's a potential for a lot of change in the way we think about waging war in that respect, and I think, all of the defense department, in fact, is moving over to more of a mind set of thinking, of taking one step back and thinking what are the effects that you want rather than just how do you do this faster, how do you do this better? Sort of evolutionary thinking, what is the effect you want? I think one of the real challenges associated with this, is that if we think about the fraction of the world that is urbanized and also the fact that the urban environment offers, for those willing to use it, some asymmetric advantages over those where we constrain ourselves in terms of collateral damage, at least to a point. So, the urban infrastructure, with all of its communication grids, its power, et cetera—in addition to the fact that it's going to all be urbanized pretty soon anyway—brings us to a state of looking at how to deal with stopping people from doing things we don't want them to do in very different ways than we have in the past. We can no longer just go in and rubble-ize whatever area to achieve the effects that we're after. I don't know that we know what the answer is except that we think it's probably going to be pretty different when you start thinking about trying to go in and take out a particular person in a particular room or stop them from doing something in a particular room or how to eliminate some bio-hazard that is being developed without, in fact, making the problem worse just by blowing it up.

J. B.: CNN even just showed it that night on the news, at the limit, all of the sudden it happens and it's so precise, so contained, who knows? That'll be a change.

B. W.: I think it's not so much just the nearer term thing, we can get there faster, we can get to something before a problem gets larger than we wanted, we can deal with it. But I think the precision aspect of it is going to become more and more important as we move to the way things look in the future and who's doing what to whom.

K. C.: But if you'll notice the precision part of it is exactly what the medical community is doing. Hey, let's don't blast away at the cancer, let's see if we can target where we want to blow it up and contain it in some sense.

UM3: I have a question for the medical community. Why did last year my father-in-law's liver surgery require a stitch that was fourteen inches long? I asked the physician in this day of minimally invasive surgery why so long and he still said, 'So I can get both my hands in' which tells me I want a doctor with small hands. I thought we were past that.

K. C.: Well, or you may want another doctor.

UM3: One who adopts technology…the guy had big hands. Had I known ahead of time I could have helped my father-in-law avoid some pain.

K. C.: Well, let me just note that anything that happens in the outer space environment—we haven't had this problem—but the first time we end up where someone needs to be operated on in space you can better well believe we'd better consider some non-invasive ways to go about it.

UM3: Or carry along the 'Handbook of Medicine for Mountaineering'? Even the sailing community uses it; it covers what to do in the rough.

K. C.: I've got one more question here but let's get the audience involved.

UM4: This is kind of out of the blue for Mr. Belk. There are rumors from your factory, the missile defense factory in St. Louis, that they're developing a missile that actually—well they need to work on the GPS system—but it's supposed to be able to maneuver actually around inner city things? To actually target certain sides of a building and everything? Is that true? Can you confirm this?

J.: I haven't even heard of the rumor and I live in St. Louis [laughter]. That might explain some of the [unintelligible] seen at night. I honestly don't know.

UF2: But the need to move in that direction is very great.

UM4: I didn't know that they had some problem with the GPS system or whatever but I just heard it and was wondering about it.

John Belk: I'll be more attune to listening to that one though.

UM5: I just wanted to add, we were talking about reliability earlier and GPS can be jammed and you can buy a GPS jammer at a French air show. So, they're going to have to have backup, they're going to have different contingencies if that system will work.

UM6: What will happen if we wiped out all GPS today?

UM6: Sure, you can't [unintelligible] going in your Hertz rental car…

UM5: Compass and a pace count…a compass and a pace count. I mean, you have to do it the hard way.

UM6: [unintelligible] they've adopted it dramatically. The military obviously would have their own [unintelligible]. But if you could successfully wipe out all GPS…I think it's a sign of a technology that's completely adopted if your life depends on it. I rely on our Air Force here to keep the skies safe.

B. W.: There's jamming GPS and what can you do about countering that from an RF perspective? But also even just in the urban environment, the GPS signals don't get through the urban canyons. And, so, then you have to look at can you, in fact, think about relaying them into other, say, longer frequencies or things of that sort to be able to use them in that sort of environment? So, right now, I don't think GPS can do that for you.

J. B.: Gyros in automotive, for example, a simple [unintelligible] gyro was what you used to get you through the tunnel…

B. W.: Right, until you come out and then reset.

J. B.: But, also, your package size is going to be huge. And I don't know if I'd want a huge package size on a missile—especially not a small missile.

K. C.: Other questions?

UM6: I have a specific question to you; would aluminum oxidizer mixed with nano aluminum?

B. W.: What I was showing was just the energy released from the oxidation of aluminum. So, you use that in explosives but you, typically, only oxidize about ten percent of the material. And, so, you're throwing away ninety percent of your explosive power in macro systems at this time. So the idea is you can actually use all of it and, therefore, be able to have a much, much smaller—I mean, a ten times smaller package to deliver the same amount of explosive impact.

K. C.: More questions? In the back?

UM7: Yes, a lot of what's been discussed has sort of been how to more precisely kill people. One of the hats that I wear in this area is I'm chair holder of Harris County Local emergency Planning Committee. Our job is to plan for emergencies and to react to those emergencies and help emergency responders. Think out of the box now, think about how some of these technologies that you're considering might be used to protect communities against weapons of mass destruction as well as the plain old garden variety, a tanker truck fell off the freeway or something?

B. W.: Well, the first obvious step is knowing that it is there in terms of the detection and you'd like, in many cases, to be able to detect without having to go right into it; and you'd like to be able to detect from a distance that you've got certain chemicals or biological materials that you don't want people to get close to—and to know which ones they are so that you then can strategize on how to deal with it. There are technologies evolving now to be able to do remote identification of whatever chemicals you actually have involved so that you can then determine what your best approach is to deal with it. There also are, um, I guess I'm thinking more on the offensive side again so, does anybody else have any thought on the defensive side?

J. B.: One thing you'll benefit from, like many industries, is just the pure computational communications. You're going to be able to, if things go anywhere near the way IBM and Motorola and such talked, have communications essentially from anywhere to anywhere at very high speed/high data rates. So, now, all of a sudden, a guy in the field gets the physician's help in Chicago, if needed. So that response should be a higher quality response just piggybacking on the nano electronics and nano photonics involvement, I'm hoping. We're going to use the bandwidth that should result in this for controlling aircraft in space, or aircraft in air, or spacecraft. There are so many vehicles in the air at one time, that's a large problem. Communications amongst those controlling a location, that's a large computational burden. Communication amongst those is a telecommunications burden, a radio burden. A lot of that will come as a matter of course. We don't have to work too hard pushing that along. When you start getting into space you have much more so, right now my company has flying around DSL-level Internet connections on aircraft, satellite link, and we're selling it to the military and we're selling it to the leaders of industry who want to maintain that level of contact today in the air as they fly from point A to point B. And that's being rolled out over time into the commercial market. All of a sudden no matter where you are on the planet, if you're in sight of any of these satellites you now can access anything you can get over the Internet, medical information, video streaming technology, software is coming as quickly as technology. So I suspect that you're going to get a broad level of benefit coming at you, just grabbing it as it comes by.

K. C.: I would add, though, that on the user side is the burden because who do you decide you need to communicate with? And what's the order and what are the priorities and what's the protocol? The technology as far as [unintelligible] and information is going to be there, but this has been a classic problem of how you decide the situational awareness and at what level do you want to spread it around? And it turns out that many users have different information requirements even though the data is all coming from the same source in some sense. That's hard. Do you have something?

UM8: I was a partner with George worrying about that problem for a long time and I don't have a solution.

UM7: I'm just wondering whether some of the things that you're looking at can reverse or can we expand the utility? You hit on a good point, communication is a critical matter in terms of protecting the community; communication between emergency responders and up and down the line and sideways, between patrol cars and fire engines and so forth. And then there's the issue of communicating hazards to the community and here, right now, we're in the horse and buggy age. We're only now planning in the county, we should have been way ahead of a system, some people call it reverse 911, in the case of an emergency that calls can be made specifically to individuals' homes. But we're so way behind the curve, and also you don't know how to communicate to people unless they are at home. What do you do if they're in a shopping center or in their car going to the university? We need to be able to solve those problems if we're going to optimize how we can protect our communities.

UM9: One problem is having increased dependence on [unintelligible] just like you comment already on a GPS system. After September 11th, all the cell phone systems were down. We have become so dependent on cell phones now; the whole cell phone network went down. So, just like a question George mentioned earlier, I think that's a major concern. If anything happened in Houston as a major metropolitan area, communication is the major issue. But if the communication network was down then we're in trouble. So, potentially, I think, we are initially comfortable [unintelligible]. So try to talk about the whole issue, like just as I said in Houston, see what we can do to help. So we targeted it for [unintelligible] all very interesting.

UM5: George, you and Bob were talking about firemen and policemen and such, that kind of communication. The little box the fireman carries and [unintelligible] screams and it still [unintelligible] screams. That's been around for quite a while. We lost two firemen a couple weeks ago in St. Louis. Just to give you a notion that for a lot of cities the technologies that they're utilizing, at best they have a box that, if the fireman is injured, knocked out or whatever, it screams for help so you can find him in the smoke. That's a fire issue. How does that thing survive and function under that environment? And make it rechargeable, et cetera. Here's what happened, though, the other day from what I gather. I've heard this in bits and pieces. This is exactly what firemen fear, firemen went in and one of the firemen did not do the little card on the board outside saying, 'I'm back out.' He went off and got a cup of coffee or whatever. The two firemen went in and got lost searching for him. That's the level of technology we provide for our fire departments. We can solve that today; we don't need to wait for nano to solve that. Nano will make it less expensive if we're lucky. That's what some of these folks have to deal with.

UM7: That's a key too because you're talking about using public funds, that means tax money, and [unintelligible] here is willing to say I'll increase my taxes a thousand dollars a year to protect our firemen or ten thousand dollars to put it in every patrol car in the country or something like that. Right now, it would be extremely expensive to get what the technology can now deliver. The unit costs there are very high. I'd love to have some technology for determining, very quickly, unknown materials. And when the anthrax scare came along and so forth we had, literally, hundreds of calls a day, "There's this white powder and what is it and what should we do?" Well, there are some answers, there are some high tech answers, there's a great machine that you can put the powder in and it gives you a nice readout and says, well, yes, that's anthrax but, no, that's baby powder and so on. The only problem is they cost $80,000 each. Do we put one of those in every fire engine? Or in every patrol car? We couldn't afford to.

K. C.: Let me comment a little bit; and I think this is getting away from the technology alone but I believe after September eleventh that it's pretty well recognized by most, I think, that the federal government has a capability to respond vigorously but some of the local city, regional, and state governments are in a real bind as to how to respond because of the exact reason you're talking about. What can we afford and, in general, when a crisis like this comes we can't just raise taxes instantaneously—that's just really not the way the world works. So it's really tough. But on the other hand I suspect that you have to do the practical thing. You have to do your dead level best to recommend something that's reasonable that gets you started but it won't be something that everybody's totally proud of and it completely does the job right and so forth. And you'll have to grow it somehow. But it's a tough problem. I'm very sympathetic and if you're in the middle of trying to do something like this it's very hard.

UM9: I have a comment on a little different track, and perhaps a suggestion for the leadership of NNI for how to help the nano initiative. I imagine that's one of the things, I think, they mentioned what was done…put some input and, uh, I run a nano research project at Johnson Space Center—it's a government thing—and there are some barriers to sharing information, to working with companies, working with other government agencies, a regulatory type issue, sometimes even export becomes an issue when we're dealing with basic science that's open source information but yet restricted by export. There are different governmental and procedural barriers, I think, to an initiative that is essentially and intrinsically multi disciplinary. And to get anywhere we're just going to have to all work together and I think some barriers are artificial, and some are very necessary. In export control, most of that is [unintelligible] essential.

K. C.: Are these at a national level?

UM9: I think the only way they could be changed is with an advocate at that level. I mean OSTP or at the science advisor level. I cannot pick up a phone and just start working with a company and collaborating. I would get into so much trouble. There are good reasons why that exists. However, maybe for this, for nano, some of those things need to be cleared aside in preference for getting the mission and goal accomplished. We have a lot of pressure and we hear some of the needs. We have emergency needs, national security needs, for these new types of sensors. I do want to drive home the point that if we're expected to get physicists, engineers, chemists, material scientists, electrical engineers, all in a room together to cooperate there are already so many barriers there intrinsically from coming through stove pipes of education, that when we add the government, industry, different government agencies, and academia in there and all the barriers to doing business and sharing information, I think it's a real big barrier to accomplishment. I don't know if anyone else has that same problem?

K. C.: You're really talking about a cultural problem.

UM5: I'm kind of on the other side of that formula. I've got an application that NASA and other companies would like to have, but I don't have a real good forum and a communication path to take that to them. And I ran into people that like the ideas at NASA that say we need to go with SBIR and STTR and all that. Well, it's just too long and it goes through the long pipe. And we're sitting there talking to each other, why can't we just continue the discussion?

UM9: Right, and the President's management agenda, this document that we're encouraged to follow as far as how we should do business, I would think there is a support at the administration level inherent in that document which is to get rid of these unnecessary barriers. Let's go ahead an allow people to do business in a competitive way. And if there's an application out there, boy, we need to take advantage of it at NASA. And that's the whole reason we're here is to break through the frontier. And this is a cultural frontier, if you will and it's a communication frontier in a way.

K. C.: I kind of take of what you're talking about is, is there a way in which some of this interaction can be facilitated in some reasonable manner so that information is at least available if some groups want to get together or something like that? Are you really talking about changing federal regulations, which is a pain for us?

UM9: That's exactly what I'm talking about.

K. C.: You're talking about changing federal regulations. [laughs]

UM9: That's what NNI is about, right? It's being industry and academia, the country's advocate for making nanoscience happen faster, cleaner. There's a company that contacted me with a really good idea, and this was several months ago. I've been trying to figure out a way to work with them and it's pretty difficult to try to figure out the way I can possibly work with them without getting into some tech transfer issues and some competitive outsourcing. For a person doing the work and with the ideas, you have two people that have similar ideas and yet were prevented. And maybe these [unintelligible] were prevented because there was a specific route to get there and it's just too long and too far.

K. C.: Do you have any comment?

UM4: I recognize the problem [laughter]. Finding a balance with that is a tough issue. I mean, there are elements to this and it's [unintelligible] national security.

K. C.: Well, let me ask Mr. Boeing and Mr. Lockheed Martin, when you work in the defense domain, is there any set approach on how you're going to use nanotechnology. Boeing does it themselves or a Lockheed Martin or are you going to sub it out to someone that you kind of have a regular relationship with? I honestly don't know the answer to the question but it is over interest in the sense that sort of a corporate strategy, they either buy it or, obviously you've got to understand the systems.

Chester Kennedy: I'll let Boeing answer for themselves, but we at Lockheed Martin are moving into the systems integration role much more so than saying that we have to be the person that builds every element of a system, whether it's the joint strike fighter or whether it's a program that we would integrate with NASA or some other customer. So we buy sixty to seventy percent of what goes into a system and we integrate it together. And part of the problem that I was mentioning about the application of some of the new technology and having moved into that role, not necessarily having the skills that we need to be able to evaluate the appropriateness of it, for those environments it's a tough challenge for us and one that we're going to have to find some new ways to come to grips with. And we're going to be looking for some help from academia and NNI and other places to make sure that skill base and that knowledge center is there to do those kind of fundamental systems.

UM9: Let me go off on a tangent on that if you would. Where do you find the experts? If I wanted to find, and didn't already know one, someone who was an expert in quantum cryptography, where would I go? You know, where is the clearinghouse for finding the expertise in the world, in the country, whatever. Let's say I wanted to know the carbon nano tubes that are red, how do I find that? I wouldn't mind seeing the NNI become somewhat of a white paper clearinghouse, or actually they had that one core source. There are a number of websites you can go get information. You can do a simple global search. But coming at it from our perspective where all of the sudden we're hearing about something, and I spent two weeks trying to find the closest to an expert in the company or I can go hit the Web and try to track down the information. What resources do I really have? I'd love to be able to just go, bang, find a white paper on a topic or find three universities who are working in the area. I don't have that without a lot of leg work.

K. C.: That's quite different from this issue you're talking about here. This is an issue that a national initiative says we want people to work together and, by the way, we have put all types of barriers in place so that, in fact, you can't work together. And those are just facts. And, so, if a country, if the United States really wants to move forward, they would have to suspend some of that legal regulation, and most of that doesn't have anything to do with national defense or that sort of thing. That's what we hide behind. But the type of thing that I bet you're talking about, I don't know the specific case but I've seen this type of thing all the time at the universities, they might find things that are almost on the verge of in all probability at the one end three million and [unintelligible]. So that's what needs to be suspended is that sort of thing to get cooperation. And that wouldn't be very difficult. A fairly intelligent group of people that average at least a hundred IQ would be able to [unintelligible].

UM9: Money is on everybody's mind, doing research nowadays because of limited funding. But if you could have NNI funding and color lists so that these barriers, these restrictions, if you could only use NASA money in this particular way or this particular group and academic money, university money, that can only go to universities, or this kind of money can only go to here and there. If you can change those stove pipes so that you can do it more mission or goal oriented, we wanted to study dispersion, well then we can put the money where it needs to be, be that a company, be that a university. And maybe be it around a SBIR, STTR. And I think those work very well for some companies. It maybe having the money flow a little bit more freely too, maybe some of the communication will follow us.

K. C.: Are you talking primarily federal or are you talking state or are you talking regional?

UM9: Whatever is allocated—I assume it's a line item from Congress for NNI or at least in the President's budget.

UM4: Would you like to see NNI in between the Air Force and some of the other pieces of the government in the SBIR process for example? This is only half the question, or half the answer, right now in SBIR you open the book and you've got Air Force and Army and special ops and what have you. Would you like NNI to be represented similarly? That limits who you give the money to, admittedly. I think you're going to say no to this?

J. B.: I would almost say to scratch it all and just start with what makes sense with NNI.

UM4: Something set up for multi disciplinary research. What makes it different? Is it the multi disciplinary aspect?

J. B.: Coordinated. Coordinated multi disciplinary without barriers. Of the NNI money, I assume that NASA has gotten some of it but it goes to headquarters and then it turns into NASA money. And now NASA money comes through an agency pipeline that's a certain color. And they go to the Air Force and DOD, it becomes DOD money. And it comes down that way, that's my assumption anyway. Whereas if NNI was a bit separate from that, if it was regulatorily separate from that to where it could say, here's what we need to do, here's the mission. This is what the community has meant and that conference is all about, we think this is the thrust area, could they put the money where NNI wants it to go as opposed to doling it out to the industries? Do we want the accomplishment [unintelligible]. Does that make any sense whatsoever?

UM3: Is there a coordinating office for NNI?

UM11: A coordinating office?

UM3: A single source? If I want to [unintelligible] NNI or something…for Texas not only [unintelligible] that are in a clear sense you can [unintelligible]. In the case of NNI is there any such office or coordinating body?

J. B.: Well, you've got Mike Roco, Jim Murday. They have other assignments but they're part of that office.

UM3: So, [unintelligible] goes through NSF?

J. B.: Well, it does. They're coming out of multiple locations. NRL for Jim Murday, for example, but they are part of NNI. And you can go to the NNI web site and get a list of names to contact.

K. C.: In the back?

UM12: Yes, I'm sorry I came in late. I had a question regarding market research and analysis for nanotech. I come out of an industry background so I know how large companies and small venture capital companies do market research and analysis for the ultimate product marketed. Regarding nanotech products, how is that going to get done, market research and analysis, determining the ultimate final market and who's going to buy the product and at what price?

And how is that going to be done? Is that going to be done at NNI? Does every company do their own? Is there any collaboration coordination of the venture capital companies that have to go to the VCs and the VCs go to the industrial banks—everybody goes to the government to [unintelligible]?

J. B.: Are you asking from the end product like sunscreen product or…?

UM12: We're from the [unintelligible] managers in nanotech products and we're trying to design some interesting science and technology that goes into a product. How do we know that there's going to be a buyer for our product? What's the fundamental market research and analysis? We've got great research going on at the university level but this whole commercialization process assumes you have a market buyer for the product.

UM13: Nothing substitutes for just going out and talking to all of the companies, there is no substitute for that.

UM12: Everybody does their own.

UM13: Oh, I can't imagine that there can ever be an alternative to that because who will you trust if the government did it? Who is paying [unintelligible].

UM12: Lockheed's not going to share their knowledge with anybody else…

K. C.: Certainly not!

UM12: Like any other typical market research, new product [unintelligible] development where you've got to go to the drawing board, you're going to determine whether or not there's a one million dollar market or a hundred million dollar market.

UM4: Of course, it's more difficult because there's probably no market at all for it. So, you've got to develop the market, that's just what that is.

UM6: In most industries, don't you have an industry association that has some level of market research that's shared with all the member companies?

UM13: Well that's true for most of the applications that I think he was talking about, at least there wouldn't be any industry group already building that. I mean, let's say that if it's an improvement in something in the chemical industry, for example, there may already be a chemical industry national group. There are multiple groups there. The thing that we study with this, there's no chance in the world they'd be studying with that. Because you can just be sure they'll be ten years behind.

UM12: Isn't there a tendency for some of the venture capitalists to be focusing on identifying nanotechnology as a point they're most interested in? So, just kind of becoming a reputation for a few venture capitalists? They're the guys to go to if you've got an application idea.

UM13: Yes, there is some of that but, still, they wouldn't know your specific area very often.

UM12: So it would kind of be a natural phenomenon, kind of a gathering of birds of a feather to some degree? Or maybe diverse applications in diverse marketplaces, there's going to be people who are in the economic community that are going to say we're interested in this technology and we'll look at a diverse application here so probably kind of a…[unintelligible] focus point.

UM13: Most of the venture capital groups, this isn't true across the board but in general, the thing that they have had experience with is in the electronic area and, so, that is what they actually are talking about. We've heard from two venture capital groups today, that would be very typical. Actually that's the farthest, one of the farthest off applications. Not the farthest I would guess but one of the farther off applications, so that's what they can be focusing on, saying well, it doesn't look too promising.

K. C.: I think near term nanotechnology will either make something cheaper or it's just going to derive some enhancement. It's the same product that you have today. They're going to make them cheaper and make them better.

UM9: That's the way to think about it. Nanotechnology just uses the same laws of physics and chemistry that we've always used in almost every business. But unless you get further utilization of those laws…

UM13: It's kind of the vacuum tube replacement example, it will do that first and then it will go to new areas that have not yet been thought about.

UM9: One of the first ones coming out is we've got a sunscreen coming quickly, we've got a [unintelligible] hair conditioner, those are known products and they're just taking market share, they're not creating the market. All of the sudden the producers of those particulates are going to sell x tons and that's pretty well known. And we start getting more complicated in the functionality and that's been [unintelligible]. Right now, you're dealing with one sunscreen manufacturer as you do that. One tire manufacturer for putting particulates in tires. Those are some of the technologies and it's very easy to figure out what you're going to sell. All of a sudden you've got a multiple of people who are using your product who are [unintelligible] using a sunscreen, hair gel. Even the simple materials are going to be complex in terms of figuring out that you already know how to do that; that's just leg work. You just mentioned today four or five product areas…

UM13: Yes, in our case we are probably studying or involved with someone, some company, in some way in probably fifty different individual applications, and it would be very difficult for us to figure out which one of those was going to hit first. Well, we know one or two that we'll likely hit first but the rest of them will probably be pretty much up for grabs. But I don't know of any alternative to doing that. That's the only way I think any new product has been developed and these will be the same.

UM3: Has the subjugation come through finding new [unintelligible] or this nano [unintelligible]?

UM13: Through our research?

UM3: Through price research.

UM13: Well, there is a combination of both. Some of our technology has come through technology we licensed from Rice Univesrity but we are also developing technology on our own and we're licensing to others. We also have outside contractors. So it's about fifty percent that came from Rice initially and then we continued to add more. So what we have is the ability to make single nano tubes and we have a lot of enabling technology, the aligning technology that was first in technology, the array technology, making Bucky papers out of it, that sort of thing. So, then those are the enablers that allow applications to be done. And then we have specific application also. What we generally do on the specific applications is work with a company directly in what we call a joint development arrangement and then we share the technology that's developing very rapidly.

[recording abruptly ends]

[end of tape, side A]

[start of tape, side B]

[recording device is activated]

UM13: [continuing in mid-sentence] Multi-walled nano tubes have been in existence for a long time and are used in a variety of applications; they just don't have quite the same properties as single-walled nano tubes but they are used. The single-walled nano tubes, most likely the first application will be electron field emission, flat panel displays in televisions. I suspect that not too far behind that will be something in the stealth type of area or shielded type of area—those are the ones that come very high [unintelligible]. And they're very straightforward applications to do.

K. C.: Okay, let me walk down the list here.

UM14: I think the problems you have using [unintelligible] nanotechnology. If you thought the most traditional [unintelligible] like what [unintelligible] so, of course, those are much closer utilization. If you're talking [unintelligible]. If you're talking [unintelligible] and say wish they only come in here, right here, commercialize one thing that what Josh was asking earlier. Basically what we can [unintelligible] lasers or chemical imbalance with sensors…so you just [unintelligible]; so it's coming along. So I'm saying [unintelligible sentences]. I think [unintelligible] was developed for jamming the [unintelligible]. But later we evolved into chemical imbalance electro sensors. Prior to September eleventh we were [unintelligible] Washington and basically come out with the whole idea of how we can support the Homeland Security issues that [unintelligible]. And what was NASA [unintelligible sentence]. So, that's where I think one of the major area…who use technology? Space has been fairly [unintelligible]. And these are [unintelligible] application, Homeland Security, and many other things. So you've got commercialization [unintelligible].

UM7: The question was already posed, we talked quite a bit about the desire to have stronger, lighter materials that are more cost effective. And the industry I'm coming from is the sub-sea, we manufacture oil and gas production equipment in a sub-sea arena. So we have most of the same issues that you have, highly reliable, safety sensitive, corrosion. You are now three thousand feet below the surface of the ocean. So, I'm very interested in the material advances that have to do with those properties. Are there any of those that are close to being commercial or are they working on those? You know, is there a company that's working on those types of materials?

UM12: I'm not aware of anything specifically. I'm aware of people that are working on things that could possibly end up over there. But if they've ever done any specific experiments in that area I'm not aware of it.

UM9: From my perspective, what I'm seeing in the materials world, is people are just beginning to ask the right questions. They've thrown everything these guys can make, or somebody can find about this nano, and then they start asking more mature questions like maybe I ought to order these things, maybe I ought to put these plates in, in some pattern with silicates. So we're definitely at maturity in my mind. Everybody's thrown in and said, 'It didn't do what I thought it would do' and has begun to learn what to manipulate.

J. B.: Now we're going to go look for more basic physics of it and try to understand.

UM9: With the right questions at hand, so give it a little time.

UM12: So is this the same order of time that, say, micro electronics could have? Micro electronics…like 2005, 2006, 2010 time frame?

J. B.: Well, it might be farther out than that because I don't know if anybody's working on it. But, on the other hand, they are working on things where the properties should apply, I think. So, then it might be faster than that, but that wasn't a very good answer, obviously.

UM12: [barely audible] [unintelligible] is surface efficient materials…like [unintelligible] multi layers [unintelligible] those type of applications that [unintelligible].

UM4: I haven't seen any I beams come out yet.

UM9: It will be a while before they can grown me a spire or a rib or a [unintelligible]. But we'll both be interested…

K. C.: Okay, let me see what else I have got down here…early applications, etc. What are early applications and how will they impact the aerospace industry? I think this is more of a science discovery and it's beginning to unfold and I think everybody in the aerospace industry is well aware of the potential and will try to stay under [unintelligible] with where it is. But in terms of predicting when you could really count I suspect it's further out, maybe even [unintelligible]; that's a relative statement.

J. B.: There's one more question on the pink card there, right?

K. C.: Yes, it says that on a macroscopic scale, Earth is a microscopic system. In fact, when viewed from this perspective Earth is a complex, perfectly functioning nanotechnology system. Yes, it's got a lot of carbon in it as I recall, composed of flora and fauna. Now with the introduction of new products and systems employing new nanotechnology will it improve conditions for human kind? What are some of the potential dangers especially when the primary force is commercialization? Well, let me address kind of the generic issue and that is most technologies, if they're really substantive, and I don't think anybody disagrees that these nanoscale technologies are substantive, are just like information technology was. Most technologies end up having all of the positive characteristics identified up front and it's only until later that you find out there may be some negatives. In this case I'm not sure what the negatives are of nanotechnology. There might be some of you in the audience that have aversion but it isn't really clear to me. Do you know of any that we should just worry about? Other than we ought to be able to model the stuff so we can predict how it works.

UM9: The thing that people need to worry specifically about, all of us have read some of these alarmist papers that are read and all they talk about, every time somebody talks about self-assembly and takes advantage of self-replication.

K. C.: Run amok.

UM9: I [unintelligible] doubt that that type of self assembly is anywhere near term to worry about. But I don't know of anything that, say, I've got to be really highly concerned right now other than we'd be concerned with anything that's new. It would be kind of silly not to be concerned about anything…

K. C.: That some unexpecteds come out.

UM14: I actually asked the same question to some guy that works at the EPA out there. And he said that it's…nano technology and carbon nano tubes are like [unintelligible] where if we really did just consider what's the good points of them, what can it do for us…well, [unintelligible] is the greatest thing ever. Now we're actually considering what bad things could happen and because of that we're going to prevent the whole thing [unintelligible]. So we're pretty much scared at being completely impartial isn't that right?

K. C.: Yeah, but in getting details on that; it's easy to come up with an image like this has happened before but I haven't really seen or heard a credible [laughs]—doesn't mean it doesn't exist now.

UM14: I don't know. I asked him because I work with him every day and I'm sure they get on my hands and I don't want to die like in five or six years, you know? That was the answer he gave me.

J. B.: At least you'll be conductive…[unintelligible] over at carbon nano technologies was a material safety issue…they produced one. Like, whoa, these guys are making a [unintelligible]. They were kind of silly. They were acting like a real producer and this was a while back. So this industry seems to be more mature and how [unintelligible], like, the new materials…keeping an eye out.

K. C.: Anybody else have any encouraging comments or questions? Are we past the time that we gave ourselves? Five minutes past? Okay, all right, thanks a lot! [laughs]

[recording device is deactivated]

[end of tape, side B]

PLENARY SESSION

Neal Lane

Phillip Bond

Richard Smalley

SESSION I: ENERGY/PETROCHEMICALS

Altaf Carim

Paul Barbara

Terry Michalske

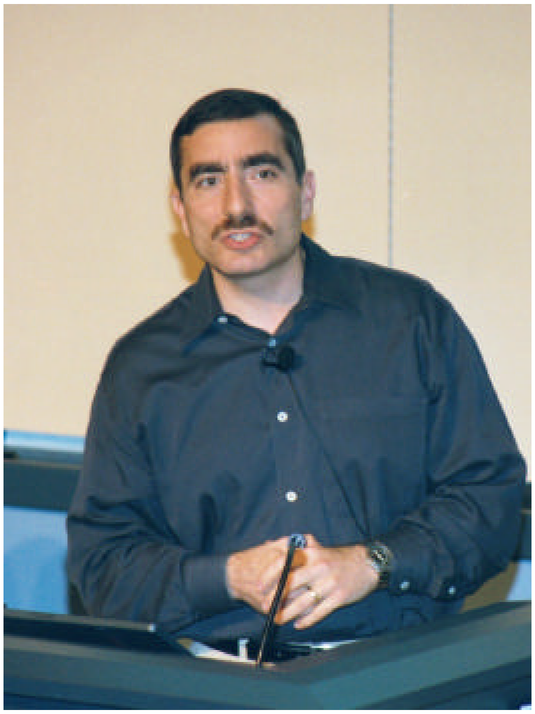
John Stringer

Chris Christenson

Lewis Norman

SESSION II: MOLECLULAR ELECTRONICS

Harold Hosack



Jim Tour

Herbert Goronkin

Daniel Leff

LUNCHEON SPEAKERS

Mihail Roco

Malcolm Gillis

SESSION III: LIFE SCIENCES

Robert Ulrich

James Murday

Edward Monachino

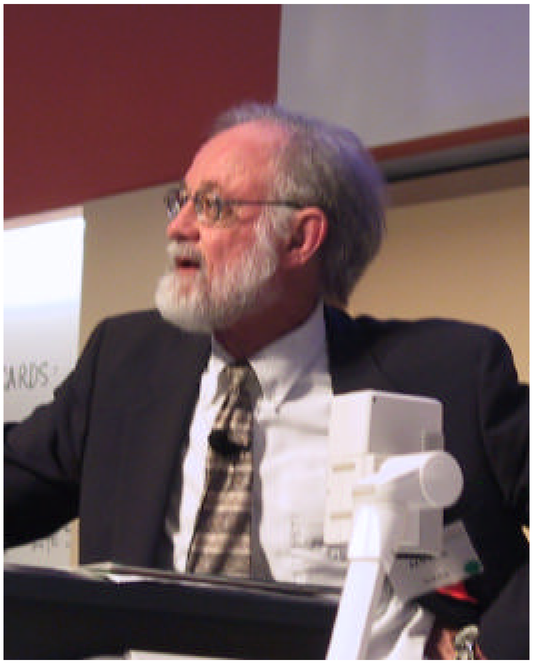
Richard Gibbs

Morteza Naghavi

Michael Rosenblum

Mary Bass

SESSION IV: AEROSPACE/MATERIALS SCIENCE



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Chester Kennedy

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Wade Adams

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LUNCHEON

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