“Nanotechnology: Opportunity and Challenge for Industry”

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Nanotechnology: Opportunities and Challenges

September 10, 2001
University of California at Los Angeles

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Supplemental Materials

EXECUTIVE SUMMARY

We are pleased to provide the proceedings of a conference entitled, “Nanotechnology: Opportunities and Challenges” held on September 10, 2001. This was the first in a series of conferences on nanoscience and technology that are being sponsored by the U.S. Department of Commerce and other Federal agencies. Additional conferences will be held in 2002 at a number of locations around the country.

Nanoscale science and engineering has been the growing focus of exciting research and discovery over the last decade and a half. A major Federal multi-agency nanotechnology research initiative is underway to enhance and facilitate the collaboration across disciplines that is required to advance both scientific knowledge and the practical applications of nanotechnology. This conference was organized to explore the status of research at the nanometer scale and its utilization by industry.

There was a special interest in how to bring the ‘nano’ into the marketplace promptly by identifying obstacles and the ways to remove them. The conference addressed three specific industry sectors - information technology, bioscience, and aerospace – and drew many of its participants from Southern California and the western United States.

Major points that emerged from the plenary session include the following:

- There is a significant wave of intellectual energy, innovation and capital in nanoscience worldwide, and the Federal Government is well poised to support research and private-sector development.

- There is particular scientific excitement for nanoscience development “from the bottom up,” building from molecule to molecular structures, as it occurs in biological processes.

- Government, university, and industry collaboration is needed most in “revolutionary” nanotechnologies that need more time to produce marketable products, most notably in microfluidics.

- University researchers are deeply involved in most successful high-technology firms, and researchers involved in commercialization are the most productive in publishing and disseminating research.

In his presentation, Dr. James Heath, scientific director of the California NanoSystems Institute, said one of the challenges in nanotechnology is to develop a "bottom-up" manufacturing approach that can take advantage of the beauty and complexity of molecular materials. It was clear throughout the conference that Southern California companies are paying attention to nanotechnology. A number of start-ups, such as Nanogen and Fluidigm, as well as mid-size companies like DI-Veeco, have products on the market with applications ranging from biomedicine to technical instrumentation. Existing companies of all sizes are examining the implications of nanoscale materials for their businesses, from chemical process improvements for conventional sensors and detectors to new materials for aerospace applications. Venture capitalists, who have identified the promise of nanotechnology, also pointed out the current constraints of the venture funding environment. Some of our scientific speakers at the conference cautioned against unrealistic early expectations and noted the blurring of lines between nanoscale phenomena and their use in "micro" systems.

Our concurrent sessions on specific industry sectors made clear how the different scientific and engineering disciplines come together in tackling the problems and challenges of nanotechnology. For biological sciences, nanotechnology brings many new opportunities, in particular for the development of new diagnostics and pharmaceuticals technologies. The opportunities for integrating the new tools and instruments for physical science with biotechnology are especially exciting. The information technology session group reiterated the need for more basic science in making the kinds of gains that are achievable with nanotechnology. The aerospace session highlighted the need for an infrastructure and system of standards to characterize things on a nanometer scale. The participants in all of the sessions made the case for new educational approaches that would bring more, and differently trained, scientists and engineers into the workforce. Conference participants expressed confidence that nanotechnology will be the basis for innovations that will drive our future economy.

As we planned and carried out this conference, of course we never imagined the events of the next day. As the nation mobilized to address the aftermath of September 11, the members of the research community looked at their opportunities, and it quickly became clear that nanotechnology could contribute to the fight against terrorism. Future conferences will examine these opportunities more closely. Nanotechnology has also continued to progress. In its traditional year-end issue that identifies the research breakthrough of the year, *Science* magazine selected research on nanocircuits as the breakthrough for 2001, saying, "In 2001, scientists assembled molecules into basic circuits, raising hopes for a new world of nanoelectronics." As we all move forward, we in the broad community interested in nanotechnology are happy to provide you with these proceedings.

EXCERPTS OF OPENING REMARKS

Dr. Martha Krebs
Director, California NanoSystems Institute (CNSI)

The California NanoSystems Institute (CNSI) is a collaboration and a partnership between the University of California, Los Angeles (UCLA) and the University of California, Santa Barbara (UCSB). CNSI was created in December of 2000 by the State of California along with three other UC-based institutions for science and innovation. It is the only one of the new institutes to focus specifically on nanoscience and technology. However, all of the institutes are expected to build the knowledge base, the human resources and the industry and academic partnerships necessary to keep California at the cutting edge of high-technology commerce in the next 50 years, as we have been for the last 50.

We at UCLA and UCSB view today's workshop as an important part of delivering on CNSI's mission.

The leadership that organized this workshop and brought you here today is shared by the California NanoSystems Institute, the UCLA School of Public Policy and Social Research, and the Los Angeles Regional Technology Alliance (LARTA). This reflects the importance of nanoscience and technology for research, regional economic development and national technology policy issues. The workshop was made possible by our sponsors from the Federal Government: the U.S. Department of Commerce, the National Science Foundation (NSI), and the U.S. Department of Transportation, along with other Federal agencies that are making substantially increased investments in the multidisciplinary research enterprise that is the National Nanotechnology Initiative.

Our purpose today is to hear from you what it will take to bring nanotechnology innovation into the marketplace in general and in your specific industries. We will be hearing about all of these issues throughout the day. We will be hearing from national and state government officials, academic researchers and industry leaders about the possibilities and problems that nanotechnology can address.

For more information, visit the CNSI website at: http://www.cnsi.ucla.edu

Barbara J. Nelson
Dean, UCLA School of Public Policy and Social Research

Breakthroughs in science and technology and their applications depend on the policy environment as much as they do on the science and environment. Our decisions have been about how the policy process is going to affect this scientific and technical and industrial effort. The questions are really just emerging, but I am sure they affect your lives now. The policy school, especially the Department of Policy Studies, brings to this enterprise the rigorous skills of cost benefit analysis, ethical inquiry, regulatory and investment policies, and democratic accountability.

There are five big policy question areas:

1) Federal funding toward basic research is the first big policy question.

2) What will the opportunities of biomedical nanoscience and technology do to healthcare costs and healthcare access and how will it affect popular support for these activities?

3) Ethics – The stem cell conversation is a bellwether. It is an indication of the kinds of questions about public purpose and public money and public investment that will parallel activities in the nanoscience and nanotechnology area.

4) The kinds of things we are looking at now at the intersection of basic science and applied science are going to make our policy decisions in the future very important. These include intellectual property, globalization, trade, and work conditions, as well as basic findings vs. patentability.

5) National security implications.

We will be called to develop ways of measuring our success that are accountable to people. It is in this area that the Public Policy School will contribute.

Bruce Mehlman
Assistant Secretary of Technology Policy, U.S. Department of Commerce

To lead in an increasingly competitive global environment, and to see Nanotechnology realize its potential, we will need several things.

First, we will need a long-term commitment to fund many years of research. Through the National Nanotechnology Initiative – a collaborative effort among Federal agencies – the Federal Government aims to ensure consistent and coordinated investments in the research needed to unlock nanotechnology's potential. But we will need sustained private investment in R&D as well.

Second, we will need to establish centers of excellence in nanotechnology that attract and support the top technologists in the world. California clearly has a commitment to leading in this field, and other states are also moving aggressively forward. With the California Nanosystems Institute right here at UCLA, the Los Angeles area could emerge as the leading nanotechnology cluster – who would have thought that anything on such a small scale could succeed so close to Hollywood?

Third, we will need to create close linkages among university, government and industry researchers, business leaders and entrepreneurs, the capital community, education and training institutions, and policy makers at the Federal, state and local levels.

And finally, we will need to make sure our policy makers "get it," and get the policies right to support innovation and development. That is why we recommended to our sister agencies in the NNI that we reach out to the business and investment communities with this and future conferences.

Joe Raguso
Deputy Secretary, California Technology Trade and Commerce Agency

California is the world's fifth largest economy. It's clear that our success is completely tied to innovation. It is clear to anyone who loves science that we only do as well as the network that we create. It is the confluence of those energies and passions that really differentiates us.

The premier areas of science and technology are going to be the most important, not only on the research and development side by also to our economic development (i.e., jobs, good quality jobs for Californians).

The challenges are great for an enterprise like this. It requires interdisciplinary research. To the businessperson, venture capitalist, and entrepreneur – everybody knows that's where the action happens, taking these great ideas and disciplines and bringing them together.

When you try to pull together an institute like that, it places in front of you the difficulty of trying to come up with the systems to keep this whole thing working, across all the Federal agencies from the National Science Foundation (NSF) to the Department of Commerce, the funds from the National Aeronautics and Space Administration (NASA), from the Department of Energy (DOE), from the state and, of course, from all the private sector interests that are here for various purposes. Dr. Krebs has no small task in front of her in keeping all this going.

The institute, and all the institutes in California, give us a set of challenges, not only the technical challenges. Along those lines, when you think about technology, especially rapid technology innovation, the impacts on society are usually not consensual. Technology creates winners and losers. Nanotechnology is in its nascent stages, and has the potential to be all these different things.

Fifty years ago there was no Silicon Valley. Now we have about 40 regions trying to be Silicon Valley. Thirty years there was no biotech industry, and 10 years ago there wasn't an Internet in the sense that we all know it now. Who knows what enterprises will be created and what medical breakthroughs will result as a result of the Nanotech Institute? We do know this: the breakthroughs will occur. I want to make sure that they occur here in California to the benefit of the California citizens.

Dr. James Heath
Scientific Director, California NanoSystems Institute

One of the challenges in nanotechnology is to develop a "bottom-up" manufacturing approach that can take advantage of the beauty and complexity of molecular materials. If you look at the technologies that have been developed over the last century, the real triumph of 20th-century science was learning how to manipulate and control either the very small (meaning the atom, or a few atoms) or the very large, a bulk solid.

For example, a graphite lattice can have massive numbers of carbon atoms, but by taking only a couple of these carbon atoms you can generate the entire lattice. The point is this bulk material, just like the small molecule, is a low information content system. On the other hand, a relatively small number of atoms pieced together in the form of a protein is very difficult to understand. When complexity originates at the level of the protein, at the level of about one to two nanometers, then you get much more complex form and function out of it, but is much more complex to understand.

It is our belief at CNSI, and I think the belief of others involved in the National Nanotechnology Initiative, that learning how to harness and control complexity at this length scale is going to be one of the emerging technologies of the 21st century. It is the scale in between what we learned to do in the last century. I want to phrase this discussion in terms of energy because the one consumable that tracks our standard of living is energy consumption. For business people, energy equals wealth, and for technologists, energy provides a thermodynamic framework for trying to understand if the physics in what you are trying to accomplish in a particular task is "young" or if it is mature. What I will try to convince you of is that the physics across the board in what we do today is young. I believe that the metric of success in nanotechnology is if we can increase the worldwide standard of living but with reduced energy consumption. Nanotechnology can be a room temperature, very "green" technology.

Nanotechnology offers improvements in the following areas of energy consumption: transportation, information technology, lighting, manufacturing, and medicine:

- Lighting: Efficiency will increase with nanotechnology.

- Transportation: Cars will be more efficient and will be lighter with new materials. Some technologies are already in use in materials.

- Information technology: Information may be treated as a physical quantity. You can calculate what it costs to do a calculation. In thermodynamic terms, a computer represents the application of a "young" physics. Efficiency is enhanced with quantum computation.

- Medicine: There is a revolution ahead in human proteomics.

Finally, once you actually do know the form and function of the proteins and how they are related to the genomes, you need to have a molecular imaging diagnosis that can take you to the isolated protein and all the way up to the cell, the organ, the organism, and the patient. In fact, one big aspect of the CNSI is to develop and encompass the imaging techniques for doing just that.

All of us in the room are reliant on the future work force, whether it is graduate students or technology workers in industry. Even with economy the way it is now, there are some 800,000 unfilled technology jobs in the nation. At the moment, students that are coming up have a very non-traditional set of skills. We have to figure out how to harness this. Kids are excited by problems, not disciplines. How do we teach to this, grab the enthusiasm that these people have for scientific problems, and take advantage of that instead of focusing on the traditional disciplines of a university?

For more information and illustrations, visit Dr. Heath's website at: http://www.cnsi.ucla.edu/people/Faculty/UCLA/heath_j.html

HIGHLIGHTS FROM THE PLENARY SESSION

Brian Pierce
Engineering Fellow and Manager of Advanced RF Technologies Department, Microwave Center, Raytheon Electronic System, El Segundo, CA.

Raytheon is looking for commercial opportunities. We are going to the investment community and looking for the market pull where we have the appropriate positioning of our technologies. Nanotechnology can be one of those and we are active in that area as well.

Raytheon is interested in nanotechnology, in particular, nanoelectronics (e.g., resonant tunneling diodes). We are focused on semiconductor nanoelectronic devices, and are working on quantum boxes, or dots, which refers to confinement of electrons to a semiconductor structure in three dimensions. This very tight confinement to a semiconductor structure gives rise to quantum mechanical effects. Therefore, nanotechnology is important in high-speed data processing and is seen as a way to improve radar and advanced sensor systems.

Nanofabrication is real and it is going on at Raytheon and other companies that use semiconductor devices. Molecular beam epitaxy (MBE) is an established technique being used at a number of laboratories and production facilities. MBE is a fabrication technology that allows one to deposit sub-nanometer layers of materials onto a single crystalline substrate. There are some new interests and advances in this area. Motorola just reported putting down gallium arsenide onto silicon. Our operation in Andover, Massachusetts actually puts an indium phosphide type of semiconductor onto gallium arsenide epitaxially, so this is a working nanotechnology.

There is a lot of excitement for "bottom-up" types of nanofabrication, which is chemical and biological nanofabrication. Building from molecules to supermolecular assemblies is an area we are not active in at Raytheon, but we need to be cognizant of the developments and explore possibilities for partnerships.

Semiconductor nanotechnology is more mature today than the chemical/biological nanotechnology for this bottom-up type of fabrication approach. One important distinction is the design, fabrication and testing infrastructure for nanofabrication or nanotechnology from a semiconductor point of view. It is much better established and has a more extensive foundation than the chemical and biological applications, so there is a need there to bring those up to comparable levels. Looking at hybrid semiconductor and molecular or semiconductor biomolecular type of structures, materials devices could act as bridges between the more mature semiconductor nanotechnology and chemical and biochemical nanotechnologies. Biosensors could be considered such an example.

Raytheon is interested in higher power devices, which are problematic when you talk about nanotechnology or nanostructures, what kind of voltages you can apply, etc. Here, however, we are emphasizing very low-power, high-speed computation. There is in existence proof that you can achieve this; the question is how can we emulate this.

There is progress being made on addressing key technical challenges to develop nanotechnology. A few are as follows:

- Fabrication of device arrays. Semiconductor approaches with lithographic techniques can do this very well; we are seeing improvements being made in the bottom-up or more nontraditional approaches.

- The connection or communication between individual nanoscale devices is something of great interest. We heard in Dr. Heath's talk about the advances made in nanowires. I would challenge the community to address how we can mimic biological processes such as photosynthesis in terms of coupling and energy transfer to better establish this.

- Heat dissipation and very efficient power generation. Again, biological processes are very good at that. From our point of view, the issues are reliability and these questions of thermal-induced errors or radiation. We have several types of platforms we put into space where radiation hardening is a real concern. When you start to make these structures very small, you have to build more redundancy into the system. A lot of interesting system trade-offs has to be considered.

As repeatedly stressed by the other speakers, this is a multidisciplinary effort. I think we certainly recognize that. That's the value of this institute and activities such as today's workshop. Finally, biology, from our point of view, would provide some very good design guidelines and architectures for these man-made nanotechnologies. So, there is our perspective at Raytheon. Thank you very much.

Steve Quake
Founder, Fluidigm Technology, Associate Professor, California Institute of Technology

I am somewhat of a nano-skeptic. The term nanoscience is so elastic that it can be stretched and distorted to describe such a broad range of topics as to almost become meaningless. I would like to talk about what I feel is the interesting part of nanoscience: the ability to fabricate arbitrary devices and machines at nanometer length scales, whether they be out of traditional hard materials, or electronic devices, quantum devices or devices made from biological materials. This element of design, and the ability to do arbitrary design, is a very important part for me. Within this aspect of nanoscience, one wants to distinguish evolutionary developments from revolutionary ones. One has the ability to fabricate devices with hundred-nanometer features right now. That is the result of this wonderful evolution in the electronics industry, and there are going to be a number of very nice ways to capitalize on this evolutionary technology.

The plus side of evolutionary technology is that it is well established, so it is going to be easy to commercialize new applications based around that, and one nice area for that is photonic crystals. However, for me as an academic, the most interesting part is to think about the revolutionary applications, which are the ones that are really going to change the way we look at things. Those of course are the farthest from commercialization. Maybe only the most speculative investors are going to think about commercializing that right now. On the other hand, it certainly is an excellent area to invest in from the government point of view and for people who have the long view and are very patient. There are a number of very interesting opportunities there; it's a fun area to think about. One should be very careful about making predictions about how soon those will come to market, because as history has shown us, obstacles pop up along the way.

In discussing revolutionary technologies, we can start with microfluidics. People began seeing the vision of microfluidics 10 years ago, and there were some companies that entered into this area early on, led by visionary people. Some have been successful in the sense that they are still around. It is clear that there is still much work to do before they become the giants that Intel and Motorola have become in the electronic industry, but we are seeing a second wave coming around and there is a greater appreciation of what the important problems are to solve. We will see successful results from both first and second wave companies but it's not the kind of thing early investors saw profits on in a three-year timeframe. For those who are patient, many wonderful things are happening now. There is a sense in the field that microfluidics is beginning to realize its potential.

Michael Darby

Warren C. Cordner Professor of Money and Finance Markets, Anderson School, UCLA

Lynne Zucker and I have spent part of the last decade trying to understand the reproducible regularities in science and technology that transfer from science to technology. In this research, three points relevant to this conference have emerged. The first has to do with university-industry partnerships, the second with the prominence of California, and the third with policy and property issues.

First, it is not a coincidence that university professors are deeply involved in most successful high-tech firms. These industries form around the relevant research universities, the top centers of excellence. These scientist entrepreneurs wear two hats. We find that if you have top scientists working within a university-firm collaboration, so there is embodied technology transfer, these firms have a 1-in-3 chance of succeeding and being one of the top-10 firms in the industry 10 or 15 years later. Without that kind of involvement of the very best and the very brightest, it's more like one in a thousand.

This brings us to the prominence of California. For the fields most relevant to semiconductors and superconductors, particularly physics, applied physics, materials sciences and engineering, and the constellation of such related fields, we see that California is very strong. Illinois started out the strongest but seems to have suffered some losses in 1998 and 1999. We speculate that people moved away from Illinois, but this is very preliminary research; we haven't gotten that far. In biological, chemical and medical sciences and engineering fields, again, California is high on the list, the highest by far. This is not surprising. Interestingly, Texas has moved up into the top ranks in this area.

What are the welfare and policy issues? First, people are concerned about university scientists involved in commercialization. We have found that university scientists involved in commercialization have more resources, and as result they do a lot more science. In terms of publishing, the university scientists involved in commercialization do substantially more publishing than those who are not at universities. In fact, they do more while they are involved in commercialization than they do before or after. Second, there is concern about the deflection of the development of science toward commercially relevant problems. There's some hint that really does go on, but it is not clear that research in other areas of science are lagging as a result.

Third, conflict of interest is among the biggest policy issues, as is its counterpart, conflict of commitment to the university. University patent offices frequently say they are judged by how much revenue they get. So they say "we want it all." Bayh-Dole set minimum royalty at 20 percent for inventing scientists. Right now the national average through market competition is around 40 percent. California's rate is around 50 percent, but it is negotiable as part of the wage contract. From the point of view of the university, the ideal share is zero. The ideal share for the investigator is 100 percent if the investigator is rich enough to be able to afford the risk. The Bayh-Dole process of getting the inventors involved in commercializing their products, along with the Advanced Technology Program (at NIST in the Commerce Department), has been very effective in the United States. In Japan, by contrast, in the past they didn't want the professors to make a dime out of the research, because they are public servants. Needless to say, technology transfer lagged there (except, of course, in the event of large cash payments, which many scientists in Japan received), because of the great cost to that economy of not having any university to firm technology transfer.

What Lynne Zucker and I are trying to do is work with our colleagues at CNSI to investigate in an emerging industry, an emerging area of science and technology, and the interplay between science, policies, property rights and commercialization. The object is to try to figure out what institutions are most effective and which institutions get in the way.

Joel Balbien
Managing Member of Smart Technology Ventures

Smart Technology Ventures is a venture capital firm focused on Southern California, from the Mexican border to Santa Barbara. Our fund is focused companies that are centered on intellectual property. Our area of expertise is telecommunications, semiconductor software infrastructure, semiconductor processing and chemical processing, as well as materials science. We are not currently involved in biotechnology.

In the venture capital industry we've had a significant level of specialization, particularly as the industry has returned to its roots of building management teams to develop strategic plans targeting and focusing on specific opportunities. Many venture funds are finding that if they form a cohesive team of experts who understand particular industries, particularly verticals, that they can have a higher likelihood of success in building these new companies, so we have focused in that area.

Smart Technology Ventures has worked with spin-offs from universities, including UCLA. When a company is spun off from a university, one of the key issues is that often the founders of the company come from the university culture, a research culture. That is different from a corporation or entrepreneurial start-up. As a result, there are challenges in melding the immense intellectual capabilities of these kinds of founders with the necessity and priorities of developing a business team that is focused, that is disciplined, and that has very specific objectives that need to be achieved for commercialization of a new technology. I like to differentiate, therefore, between corporate spin-offs, university spin-offs, and other types of start-up companies.

Background for commercializing nanotechnology: Clearly these are not the best or worst of times, but certainly are challenging times in high technology. We are in a kind of cyclical recession in the technology sector. The downturn seems to be very concentrated in telecommunications. We've had these cycles before going back to the mid-1970s and the mid-1980s. They are tied to the general economic cycle and global economic conditions, but also can be specific to certain industries that have built up a certain level of over-capacity, where demand has not really kept pace, or where revenue and sales have not kept up with expectations. Certainly with the Internet boom there was tremendous excitement and enthusiasm about telecommunications, but we've faced bottlenecks and challenges. We've gotten ahead of ourselves in building some of the infrastructure that supports the Internet, and we're seeing some of the pain of that now in terms of the over-capacity in our optical backbone and so forth.

Returns to venture capital funds and to corporations investing in venture capital have declined and gone negative. There have been some major write-offs by large corporate funds. There has been about a 90 percent reduction in corporate venture capital investment.

We are seeing a venture capital (VC) investment climate that is dominated by the traditional kind of VCs. There is definitely a tendency for companies to move down the risk-reward curve. You expect this in a recessionary environment. Venture capital firms are investing in later-stage companies, and they're putting a lot more focus on their existing portfolio companies, so there is this kind of shift from early stage to later stage investing. There also seems to be a shift in the segments that are attracting capital, which is also going to be interesting from the standpoint of emerging nanotechnology companies.

Clearly there has been a massive decline in e-commerce companies, and that has then been followed by a major decline in investment in optical communications and in some of the related telecommunication segments that supply the infrastructure applications for those e-commerce companies. At the same time, we've seen a steady increase in investment in biotech and healthcare-related companies. That is a very interesting trend that needs to be noted particularly by nanotechnology companies that are looking at using biological or other types of similar systems.

Again, I think the recent trend in shifting investments to later-stage companies is going to continue. You tend to see more money being invested in those situations.

Venture backed IPOs have pretty much collapsed, so we're not seeing a lot of exits. That explains some of the negative returns we are seeing as well. So, if you are planning to start a new nanotechnology don't expect to go IPO any time soon. There's a big backlog ahead of you. The bar you have to achieve, in terms of what does an emerging company have to demonstrate to go IPO, has gone a lot higher than it was a few years ago. You have to show that you have a sustainable business model and that you can generate revenue and earnings in some predictable fashion that analysts can utilize to make sensible valuations.

When setting up a new company, think about what you need to do to be attractive as a potential acquisition. A much larger company hopefully will pay a good premium or good price for your company and allow the company to continue to develop its technology and penetrate the market.

Even though investment activity has declined, the amount of money flowing into venture capital has continued to be quite strong. It will be down from last year, but nevertheless about $50 billion will probably be flowing into new funds this year. That's partly driven by the fact that pension funds as well as other institutional funds have been allocating an increasing part of their portfolios to venture capital. The percentage that these funds are investing in VC has actually gone up from the traditional five percent and now is being targeted at as high as 15 percent. So at a time when it's getting difficult to profitably deploy that capital and returns are going negative, there is still a momentum of flow of capital into the industry. That is good news for entrepreneurs who are forming companies. It means there's a large pool of capital out there looking for opportunities, looking for highly disruptive technologies that have the potential of launching the next big billion dollar companies.

In summary, there are implications of the environment we are in now and for the next couple of years. Venture capitalists want to avoid science projects that should be funded by the government, universities or corporate labs. These are not likely to get funded in the current environment at least and they are difficult in any case. VCs want to think about achieving first revenue in three years or less. That reflects the more near-term focus and the risk aversion that's out there among investors.

We need to work on the way we regulate these technologies and take into account that we are really on a new frontier, working at the molecular level, and so we're going to have to think about the fact that you just don't regulate the same way. I think there needs to be progress and change in that area.

Mihail C. Roco
Senior Advisor, National Science Foundation
Chair, NSTC Subcommittee on Nanoscale Science, Engineering and Technology

I see in this event an opportunity to better connect the National Nanotechnology Initiative research providers and industries with each other, and eventually to build connections between industries that are already involved in the field, and particularly to involve new industries in nanotechnology. At this moment we have a relatively small number of companies involved in nanotechnology. One objective, in the interval of a few years, is to spread the idea that companies need to prepare for a paradigm shift that will happen 10 years from now throughout U.S. industry.

We have advanced the idea that nanoscience is not dealing with small things, but with new phenomena. Nanoscience is providing a unity in science and engineering, creating the tools for a more efficient length-scale for manufacturing. Rearranging matter at the nanoscale creates the opportunity to do anything more economically with smaller amounts of material and smaller amounts of energy. I should mention that this effort is already ahead of schedule. When President Clinton announced this initiative he said, "Imagine things that can happen in 20-30 years," and took three examples. Those three ideas that he proposed: molecular electronics, nanotube reinforced materials, and detection of cancer, all are already in a much more advanced phase of development than predicted.

A major change in perception is that industry now recognizes a paradigm shift in nanotechnology. Whether in molecular electronics, quantum computing, or DNA, in 5-10 years there will be a change in paradigm. The United States now has a leadership role in electronics, biotechnology and several other technologies. Nanotechnology is a condition for their progress in 10-15 years. How we manage nanotechnology development will be of strategic importance for the United States.

The United States increased the investment in NNI by 56 percent last year. All over the world the increase is more than 75 percent in the same time interval, following about six months after the United States. This is because most countries, like Japan and the European Community member states, start the financial year in April or March, whereas the United States starts in October. Our development has influenced their programs. The NNI is focused on an interdisciplinary 'horizontal' development of nanoscience and nanotechnology, while in other countries we see a more pronounced government interest in the 'vertical' development from research to specific technological areas.

In the 2001 when we started the financial year, we had six agencies involved. Now we have 15 departments and independent agencies involved, as can be seen on our Web site at *http://nano.gov.*

A little history: Informally, the group started at the end of 1996. We did our homework relatively quietly, and prepared about five documents. One was a worldwide study reviewing what was happening in the field, and one was on nanotechnology research directions. Later, we developed additional materials such as the brochure for the public and the report on societal implications for nanoscience and nanotechnology. In Oct. 1998, this bottom-up activity was recognized by the White House and an interagency working group was appointed under the National Science and Technology Council (NSTC). The working group was elevated in 2000 to the level of an NSTC subcommittee. In fact, within the Committee on Technology there are two equally active subcommittees: information technology research and nanotechnology.

A few questions related to this group: First of all, how will we interact with industry? On *nano.gov* you will find the list of calls for proposals and other announcements. In most of them we encourage interaction with industry. For instance, NSF does not fund industry, except under the SBIR program, but we encourage partnerships.

We seek to create a database on developments in this field. We have user facilities, for instance NSF has a national nanofabrication user network in which five universities have been identified as research institutions (see *http://www.nnun.org*). The Department of Energy is creating three new user facilities. NASA plans to create three university-based facilities this year, and the Department of Defense a new university-based center.

NIST will provide assistance to industry in instrumentation standards and manufacturing. At NSF, three years ago we had about four new awards under SBIR program in the field of nanotechnology, last year we had about 30 awards including STTR, and this year we have more than 100 proposals in review. We are developing partnerships with different industrial groups, for instance with the Semiconductor Industry Association. We plan to create a database of companies; the results will be posted on *nano.gov.* We are holding a series of workshops like this, the Department of Commerce has taken the lead, and we hope at the end of this series to prepare a document for industry to encourage networking, continuous mechanisms of interaction, and better connections with and among research providers and research users.

Another key challenge for the United States is to create the workforce for nanotechnology that will be needed 10 to 15 years from now. We are working on curriculum development, including new courses. We train interdisciplinary groups, and fund fellowships for students that can move from one department to another and work in nanotechnology. Currently there are seven such groups. One such group is at the University of California at Davis, another at the University of Washington. These are distributed around the country and we will continue to fund them.

NNI priority in funding for FY 2002 will be given to: research to enable the nanoscale as the most efficient manufacturing domain; innovative nanotechnology solutions to biological-chemical-radiological-explosive detection and protection; development of instrumentation and standards; the education and training of the new generation or workers for the future industries; and partnerships to enhance industrial participation in the nanotechnology revolution. The convergence of nanotechnology with information technology, modern biology and social sciences will reinvigorate discoveries and innovation in almost all areas of the economy.

In conclusion, within 10 to 15 years from now nanoscale science and engineering will affect our lives in a significant manner. In the beginning it will be so-called "rudimentary nanotechnology," but it will become more complex in time. Significant implications will be on knowledge and our comprehension of the world. Industry, the medical field, and sustainable development will be core areas of transformation.

HIGHLIGHTS FROM THE BREAKOUT SESSIONS

Session I – Bioscience

There is plenty of room in the nano/bio area for additional funding. That is, there is room for excellent science to be funded.

There are opportunities for new technologies such as diagnostics and pharmaceuticals arising from biochips.

There is a lot of science that has application but there are only a few examples of companies that have been spun off with varying levels of success.

"Nanotechnology" must be defined, as it exists; whether or not it is a field or a set of tools or if it is manipulation at the molecular level or knowledge of interactions of systems. We need to discuss what are the defining elements that make us able to talk about nanotechnology.

Science isn't that much of the issue in industry; manufacturing and manufacturing for reliability are. Reliability is a major issue in bringing a product to the marketplace.

The role of legislation in giving federally funded organizations the right to take title to their intellectual property is seen as an important policy issue.

The introduction of new drugs requires a discussion between insurance/HMOs and physicians who do not easily talk to each other. Whether or not you do that in a framework of a regulatory process or in some other kind of engagement is something that needs to be addressed.

New technology and interaction in personal lives. Privacy issues, economic accessibility, information and full consent – all of these are seen as topics that will arise as we move forward with nanotechnology applications and insertion into the marketplace. We need to be prepared for that.

We need some kind of infrastructure at the universities, as well as the curriculum to prepare the next generation of scientists and engineers. That was really the state's intention when it created all of the institutes for science and innovation, and in particular the CNSI.

Networking – more is better. It is important to include (at these meetings) regulators and other government representatives such as Congress, the FDA, and the Patent and Trademark Office.

Session II – Information Technology

More basic science is needed. Over the next few years we are going to bump up against the limits of what current technology can do. Breakthroughs in basic science will be needed to move us into different directions to make the kind of gains we want.

The Internet boom has provided a compressed version of the historical cycles of discovery, popularity, hype and crash. From the financial point of view, this is a good time to proceed in nanotechnology research and development in order to be ready for the wave that will occur.

The government is looking for guidance about where it can it put its money to get good effects and leverage it the most effectively.

Nanotechnology makes more sense as a field as opposed to artificial intelligence, which is too broad. Ways to avoid the hype-boom-crash cycle that AI goes through in every 10 or 15 years must be explored in order to avoid some of these excesses.

Questions that have already been raised include the "gap" between science and the commercial marketplace. There is a bridge that needs to be crossed, from university laboratory to something tangible that a commercial venture can pick up.

It is important to get the right balance, the right mix, of people (business, government, scientists, etc.) at these conferences.

California may be considered the center of nanotechnology. This is important for the state as well as for new companies getting into nanotechnology.

Nanotechnology needs a single disruptive or "killer" application. At this time it is not clear what that is or will be, but a universal application that is readily comprehended will certainly raise consciousness toward nanotechnology.

Session III - Aerospace

The aerospace industry is a cauldron for the development of nascent technologies and the science associated with those technologies, for historical reasons. One foreseeable benefit and goal of nanotechnology related to the aerospace industry may be the production of cheaper satellites with extended mission life.

At this point, the fundamental obstacle is that "people still don't know what nanotechnology is." There is at present a lack of infrastructure to characterize things on a nanoscale. Standardization will remain a major issue. There is a need for NIST to set standards in nanotechnology as it does in many other areas.

Large companies like Boeing will pick up on new technologies once they are made available (e.g., in the form of materials) for use in their products. The immediate needs of industry and companies like Boeing can be summarized in the following way: "Nanotechnology is here. When it is ready, we will adopt it." These new technologies may come through the automotive industry. When they are developed, they will be incorporated into the products of other companies. One example is weight reduction in structural materials of vehicles or aircraft, resulting in increased payload capacities.

Everyone is trying to make stronger, lighter materials. Companies already working in metals, for example, will try to make stronger and lighter materials. Progress in nanotechnology will encourage this type of development in established industries.

Products based on innovations in nanotechnology will appear. Accordingly, investors will follow successes. When disruptive technologies strike, there is a corresponding response from traditional industries. While nanotechnology, like other emerging technologies, may be overestimated, in the long run nanotechnology "will outdistance our wildest expectations."

Tools are needed to test and validate the progress of nanotechnology. This is because the cost of failure on the civilian commercial side in aerospace is very high. However, the field will be full of opportunities and, although companies will need compelling reasons to adopt products, nanotechnology will touch all areas from space to electronics to healthcare issues.

Since we are moving toward self-assembly in nanotechnology, the concept of scaling is important in order to "wrap ourselves around nanosystems." As a practical matter, self-assembly will be needed to build useful structures at the molecular level.

New products and materials will make a gradual paradigm shift to multifunctionality. Consumers will expect more intelligence per mass from products. For example, clothing might contain physiological monitors.

The government's role and involvement in the progress of nanotechnology is important for this interdisciplinary field to evolve. This field will need support from government to make sure that there is funding for commercialization and research. Funding should encompass the concept of "gap funding" to address the gap between basic fundamental research and commercialization. There is a chasm where businesses can become lost and are not viable due to lack of funding.

Nanotechnology programs must be legitimized over time. Metrics on private revenue, external investment and jobs created will be needed to legitimize nanotechnology. This is important as a tangible measure of viability in the research area.

There is a consensus that more meetings like this are needed and that government should be involved. As nanotechnology progresses, large companies will get to know small companies and a database of information will be needed. This information should be available for the financial community because at present the understanding of nanotechnology "can be described in whatever terms you desire."

Because nanotechnology is multidisciplinary by its nature, interdisciplinary training programs at the high school and university levels are required. This necessitates the re-establishment of a school curriculum that includes areas such as quantum mechanics.

KEYNOTE REMARKS

An Extraordinary Time in the Sciences

Albert Carnesale, Chancellor, University of California, Los Angeles

Welcome to UCLA. And thank you for taking part in today's workshop on "Nanotechnology: Opportunity and Challenge for Industry." I'm delighted to see this distinguished group of leaders, representing industry in Southern California, to be sure, and also representing the arenas of finance, technology, education, and government. The breadth of your own activities and interests is indicative of the sweeping impacts that advances in nanotechnology undoubtedly will have on our society. I want to thank the UCLA sponsors of today's program: the California NanoSystems Institute, directed by Martha Krebs, and the School of Public Policy and Social Research, led by Dean Barbara Nelson. And I want to acknowledge the other entities responsible for this workshop: the U.S. Department of Commerce, the Federal Aviation Administration, the National Nanotechnology Coordinating Office, the National Science Foundation, and the Los Angeles Regional Technology Alliance. Many thanks to all of you.

This is an extraordinary time for most fields in the sciences. Consider the "new biology," the dazzling advances in biomedicine and genetics; the IT revolution; biomedical engineering; and the rise of whole new fields such as bioinformatics. Nanotechnology is among the most exciting – and the most promising – of these developments. To be able to manipulate structures at the molecular level – atom by atom – is to achieve unprecedented understanding and control over the fundamental building blocks of all physical things. As you know, future advances in this technology could transform the way almost everything is designed and made. As you also know, advances in this technology raise a host of important and compelling policy questions. Such questions have brought you together today, and I commend all of you, not only for seeking the best answers to these questions, but for confronting them now, while the field of nanoscience is still in its infancy.

The Federal Government has joined with the scholarly, technical, and academic communities in recognizing the vast potential of nanoscience. And so we have the National Nanotechnology Initiative, worth half a billion dollars, as a top science and technology priority for the United States. Naturally, UCLA is pleased that 70 percent of the new funding proposed under the Nanotechnology Initiative will go to university-based research. In keeping with the land-grant tradition, public universities such as UCLA have a distinguished history of conducting basic and applied research to benefit our communities, our states, and our nation.

The National Science Foundation has played an important role in those partnerships for half a century now. As part of its 50th anniversary celebration, the NSF compiled a "Nifty 50" list of "NSF-funded inventions, innovations, and discoveries that have become commonplace in our lives." Number 28 on that list is the Internet. Through the efforts of Professor Leonard Kleinrock and his graduate students, UCLA became one of the first nodes on the ARPANET, the interconnection of networks that eventually became the Internet. Number 8 is Bucky Balls – the geodesic-shaped carbon molecules noted for their strength. A distinguished team of scholars from UCLA's Department of Chemistry and Biochemistry has made important contributions to this field, as did UCLA Professor Jim Heath [scientific co-director of the CNSI], when he was a graduate student at Rice. And number 33 on the list is nanotechnology. UCLA is asserting itself as a leader in this emerging field.

University-government partnerships are more important now than ever. And often they are three-way partnerships involving the private sector as well – which is the case with the California NanoSystems Institute at UCLA and UC Santa Barbara.

In December 2000, Governor Gray Davis named the California NanoSystems Institute as one of three "California Institutes for Science and Technology." The state is providing funds to these institutes in order to propel the California economy forward and benefit all Californians. CNSI is a broad-based effort; a series of partnerships:

- Two UC campuses – UCLA and UC Santa Barbara.
- Other universities (including Caltech).
- The National Laboratories managed by the University of California.
- The private sector– 30 corporate partners to date, including Hewlett-Packard and Sun Microsystems.
- A variety of academic disciplines are involved – including the physical and life sciences, engineering, medicine, and policy studies.
- A partnership between the people of California and their state.

The team we have assembled to lead the institute is impressive in the scope of their knowledge, in the breadth of their experience, and in the expanse of their imaginations.

- Director Martha Krebs, the former director of the Office of Science, U.S. Department of Energy.
- Scientific Co-Directors James Heath, UCLA Department of Chemistry and Biochemistry and Professor Evelyn Hu, UC Santa Barbara Department of Electrical and Computer Engineering and Materials.

The institute is poised to explore all aspects of nanotechnology. I like to think of it as a prototype for the "centers of excellence" envisioned by the National Nanotechnology Initiative – research centers that develop and use the tools of this emerging discipline, while also building the partnerships crucial to advancing the discipline in years to come. This is not an entirely new role for research universities, given our long-standing partnerships with Federal granting agencies such as the National Science Foundation… But it reflects the fact that research universities like UCLA are ideally positioned for, and equipped for, advancing knowledge that will have both societal and economic advantages. We are enormously proud of the CNSI, and what it means for the future of UCLA, California, our nation, and beyond.

I'm told that today's workshop is the first of several to be held in the next 18 months throughout the United States. I am delighted and proud – but not surprised – that this process is starting here at UCLA. Again, I am pleased to welcome you to our campus. I trust that your continued discussions will be fruitful, and I hope that you will continue to turn to UCLA for innovation and leadership.

Shaping Policy for Nanoscience Development

by Bruce Mehlman, Assistant Secretary of Technology Policy
U.S. Department of Commerce

It's truly an honor to be here today. I am still awed every time I get the chance to speak on behalf of the United States Government. And I'm sincerely humbled to be in the company of such distinguished leaders, entrepreneurs, innovators and visionaries.

We live in an incredibly exciting time. The Wright Brothers probably thought the same thing down in Kitty Hawk, North Carolina, nearly a century ago. Little did they realize that only 66 years after their 12 second, 125-foot flight, our quest for discovery and desire to overcome the apparent limitations of natural laws would take us to the moon and back.

I can only imagine what the world will look like when my children reach my age. But imagining that world – and trying to shape it – is precisely what brings us all here today.

Nanoscience and nanotechnology stand as the next great frontiers for exploration and conquest – perhaps the greatest frontiers we've ever faced. The ability to manipulate matter at the atomic level – to build new materials and devices molecule-by-molecule – promises more change in the next 30 years that we saw in all of the 20th century.

For example, imagine single molecule transistors, or computer switches that are only 3 atoms thick and can assemble themselves. Imagine smart drug molecules that patrol your blood stream and release antibiotics only in the presence of an infection. Well actually, you don't need to imagine those things. They're already here. Companies are already using nanotechnology to make plastics stronger, paints more durable, semiconductors faster and clothes more UV-resistant.

And if you're as impressed as I am by these existing developments, just wait, because we've only scratched the surface. Imagine having your clothes respond and adjust to changing weather conditions, monitoring you vital signs, and protecting wounds. Imagine programmable machines that travel through your bloodstream, supplementing your immune system or performing genetic surgery, or artificial red blood cells that permit scuba diving without oxygen tanks or keep your organs safely oxygenated 4 hours after your heart stops beating.

With such incredible possibilities, it is no wonder the National Science Foundation predicts the market for nanotechnology-based products and services will reach over $1 trillion by 2015 in the United States alone. Leading experts gathered by NSF predicted that nanotechnology's impact will be at least as significant as antibiotics, the integrated circuit and man-made polymers were in the 20th century.

Of course, Americans are not the only ones to recognize the importance and potential of this emerging field. While we're putting $422 million into nanotechnology R&D this year, foreign investments will total almost twice that at $835 million. Everyone expects that the first country to make the big breakthrough may be poised to become the economic giant of the future.

To lead in an increasingly competitive global environment, and to see nanotechnology realize its potential, we'll need several things. First, we'll need a long-term commitment to fund many years of research. Through the National Nanotechnology Initiative – a collaborative effort among Federal agencies – the Federal Government aims to ensure consistent and coordinated investments in the research needed to unlock nanotechnology's potential. But we will need sustained private investment in R&D as well.

Second, we'll need to establish nanotechnology centers of excellence that attract and support the top technologists in the world. California clearly has a commitment to leading in this field, and other states are also moving aggressively forward. With the California Nanosystems Institute right here at UCLA, the Los Angeles area could emerge as the leading nanotechnology cluster – who would have thought that anything on such a small scale could succeed so close to Hollywood?

Third, we'll need to create close linkages among university, government and industry researchers, business leaders and entrepreneurs, the capital community, education and training institutions, and policy makers at the Federal, state and local levels.

And finally, we'll need to make sure our policy makers get it, and get the policies right to support innovation and development. That's why we recommended to our sister agencies in the NNI that we reach out to the business and investment communities with this and future conferences.

At the Office of Technology Policy in the Department of Commerce, our job is to partner with industry to promote policies that maximize technology's contribution to U.S. global competitiveness and innovative capacity. We try to support the commercialization of existing technologies by identifying and building supportive policy frameworks, and we strive to anticipate policy barriers to the successful commercialization of critical emerging technologies.

Nanotechnology already presents significant new challenges for policy makers, with more likely to come. For example, can our health care systems accommodate dramatically new procedures, drugs and opportunities? Can our education systems rethink their organizational structures to produce technologists with the multi-disciplinary expertise required? What will our public safety infrastructure need to protect against new, deadlier threats and the inevitable unintended consequences of a paradigm-shifting technology, such as quantum computing that can break any encryption? How will longer life-spans impact pension and entitlement systems, or workforce needs and supply? What will these new technologies mean for our privacy, and how will consumers react when we offer them nanorobots to travel in their blood – which, let's face it, are a lot scarier than so-called "frankenfoods" or nuclear power? How do global economies prepare for the ultimate disruptive technology, one that could tear down as many businesses and business models as it generates? And how might we ensure that the United States and our citizens are the first to capitalize on the economic, military and social potential of nanotechnologies?

Of course nanotechnology also offers great opportunities for policy makers, and it is incumbent upon us to identify and aggressively pursue them. Nanotechnology could improve our environment, reducing worldwide energy consumption, de-radiating nuclear waste and counteracting pollution. It could solve scarcity challenges that keep food, safe water and quality health care out of reach for too many people.

With such serious stakes, it's very important to get the policies right. That is where efforts such as this conference become essential. This workshop is the first in a series that will be held throughout the country, aiming to bring the insights, needs and opinions of industry and academic leaders together with government policy makers and researchers.

It will take a public-private partnership to ensure we get the billions of dollars, millions of research hours and thousands of committed scientists we'll need to realize nanotechnology's potential. We will need to work together to ensure a stable and supportive policy environment, identifying barriers and recommending solutions. And we'll need to broaden our community even further to find the wisdom required to use these new powers with, prudence, care and humility.

The good news is that the Bush Administration is very committed to science and technology. Since taking office, the President has asked Congress to put $1 billion into improving math and science education; asked for trade promotion authority to remove barriers to the free flow of goods, capital and information; and proposed the highest funding levels for basic research in the history of the country – $95 billion for 2002. And President Bush proposed increasing Federal investments in the National Nanotechnology Initiative by 23% to $519 million, in 2002.

We look forward to learning from you today and working with you going forward. And we thank you very much for joining us today.

WORKSHOP CHARTER

Nanotechnology: Opportunity and Challenge for Industry

Nanoscale science and technology reaches across the traditional scientific and engineering disciplines and arises from the growing confluence of knowledge and tools that permit the molecule-by-molecule observation, manipulation, or assembly of biological and inorganic materials. The applications of this knowledge will reach broadly: molecular and spin electronics that will provide a new technology base for computing; energy efficient processes for fabricating near net shape devices and coatings; multi-functional materials intentionally designed and self-assembled; new technologies for national defense; diagnosis and treatment of disease at the molecular scale rather than symptomatically.

Both large and small companies have begun to invest in the revolution that is underway at our Nation's universities. The Federal Government has created a multiagency National Nanotechnology Initiative that is providing more than $500 million annually to support research at and collaborations between universities and industry. 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 provide the next generation of scientists and engineers, who will create and develop "nanoapplications."

This workshop will bring together leaders from industry, government, academia and the financial community to explore in more detail their views on the future of nanotechnology. The workshop is planned as one of four over the next 18 months in various regions of the country. This workshop will draw attendees from the western United States predominantly and will focus on the importance of nanotechnology to three areas of application: aerospace, information technology/electronics, and biotechnology/medicine.

In each of these areas, the workshop will address questions such as:

- What are the major technical challenges these industries face in order to exploit nanotechnology?
- What scientific opportunities or trends are on the horizon of nanotechnology that have not yet been fully captured by industry?
- What are the major obstacles that prevent the investment in and application of new nanotechnology in these industries; e.g., in the financial, regulatory, or policy arenas?
- How can we facilitate the networking of industry, business, academic and government organizations?

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

The workshop will take place at UCLA on September 10, 2001 under the leadership of the California NanoSystems Institute and the UCLA School of Public Policy and Social Research. The principal sponsors are the Department of Commerce, the Federal Aviation Administration, the National Nanotechnology Coordinating Office and the National Science Foundation.

BIOGRAPHIES

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Dr. Joel Balbien was a manager of Smart Technology Ventures I and II, and is a Managing Member of Smart Technology Ventures III. He has worked with STV's founder, David Nazarian, for three years building Smart Technology Ventures' portfolio of more than forty companies. Balbien now serves on the boards of directors of Transilica, Inc., Holl Technologies Company, Eternal Systems, and Maxoptix, and as a Board Advisor for Continuous Computing Corporation. Dr. Balbien has been a frequent speaker within the venture capital community including presentations at LARTA conferences and the MIT/Caltech Forum. He has also served as a mentor for the Southern California Venture Capital Forum.

Prior to joining Smart Technology Ventures, Balbien was vice president of business development for a private aerospace holding company and an assistant treasurer at Sempra Energy (formerly Pacific Enterprises). He also worked as an operations research analyst for the Jet Propulsion Laboratory. Balbien received his M.S. and Ph.D. from CalTech.

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Mr. John H. Belk is an Associate Technical Fellow in the Phantom Works at the Boeing Company. He has developed and nurtured various aerospace-related technologies to solve specific system and manufacturing problems. He has over 22 years of experience in testing and quantitative evaluation of materials and optical systems for all stages of the product's life. He has contributed to new manufacturing processes for composite materials, optical fiber sensors for smart structures, MEMS-based sensing systems, and satellite-to-satellite laser communications while conceiving, winning, and managing millions of dollars in research and development funding for Boeing in these areas, obtaining six issued patents along the way. He is now working with others across the Boeing enterprise to develop a coordinated nanoscience/ nanotechnology plan for all of Boeing's activities. He is or has been a member of the Optical Society of America, the American Institute of Aeronautics and Astronautics, the International Society of Photo-Instrumentation Engineers, the American Society of Mechanical Engineers, and the Society for the Advancement of Materials and Process Engineering.

Scott Broadley
Vice President
Broadley-James Corporation

Scott Broadley is the Vice President of Broadley-James Corporation. He received his B.A. in Chemistry from the University of California, Davis in 1978. He has designed, engineered, and developed electrochemical sensors for over 20 years. He co-authored a paper on pH monitoring of pure water (Wilson, D. L.; Broadley, S. T. Proceedings of Ultrapure Water Expo, Philadelphia, April 2-4, 1990.), and co-authored two ASTM procedures on high-purity water pH measurement. In addition, in 1992 he was granted a patent for a pH sensor (U.S. Patent #5,147,524 and Canada #2,060,946). His knowledge of electrochemical sensors, expertise in designing and bringing to market numerous sensors uniquely qualifies him to lead in the development of a microfluidic flowing-junction pH sensor.

Albert Carnesale
Chancellor
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Albert Carnesale became Chancellor of UCLA on July 1, 1997, and was formally inaugurated on May 15, 1998, as the eighth chief executive in the University's history. He holds faculty appointments in the Department of Policy Studies at the School of Public Policy and Social Research and in the Department of Mechanical and Aerospace Engineering at the School of Engineering and Applied Science.

Before assuming the helm of UCLA, Chancellor Carnesale was at Harvard University for 23 years, serving in numerous capacities. He joined the Cambridge campus in 1974 as the Lucius N. Littauer Professor of Public Policy and Administration at Harvard's John F. Kennedy School of Government. His teaching and research endeavors focused on international security and arms control, with an emphasis on policies associated with nuclear weapons and strategies for their use and non-use; international issues related to nuclear energy; and the impact of technological change on defense and arms control policy. In 1981, he assumed the role of the Kennedy School's Academic Dean, acting as the principal advisor to the Dean on matters of faculty personnel, research, and teaching. In November 1991, Dr. Carnesale became Dean of the Kennedy School, serving as its principal academic and administrative officer. In this capacity, he directed the activities of 100 faculty members, 70 researchers, and 350 staff personnel.

July 1994 saw Dr. Carnesale's appointment as Provost of Harvard University. As Provost, he served as Deputy to the President of the university, oversaw academic and administrative programs, coordinated the work of Harvard's central administration, supervised information-technology activities, and represented the university in external affairs and development. Earlier in his career, Dr. Carnesale was a member of the faculty at North Carolina State University from 1962 to 1969, and again from 1972 to 1974. In the intervening years, he held a position in government as part of the U.S. Arms Control and Disarmament Agency from 1969 to 1972. In addition, he worked in private industry for Martin Marietta Corporation from 1957 to 1962.

Dr. Carnesale earned B.M.E. and M.S. degrees in mechanical engineering at Cooper Union in 1957 and Drexel University in 1961, respectively. In 1966, he received a Ph.D. in nuclear engineering at North Carolina State University.

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Scott R. Carter is a Licensing Associate for the California Institute of Technology's Office of Technology Transfer. He manages Caltech's Life Sciences patent portfolio and is responsible for licensing a variety of technologies. Scott received a Ph.D. in Chemistry from Caltech and is a registered Patent Agent.

Michael R. Darby
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The Honorable Michael R. Darby currently serves as the Warren C. Cordner Professor of Money and Financial Markets in the John E. Anderson Graduate School of Management and in the Department of Economics at the University of California, Los Angeles, and as Director of the John M. Olin Center for Policy in the Anderson School. He is also Professor of Policy Studies at the UCLA School of Public Policy and Social Research. Professor Darby served in a number of senior positions in the Reagan and Bush administrations including Assistant Secretary of the Treasury for Economic Policy (1986-89), Member of the National Commission on Superconductivity (1988-89), Under Secretary of Commerce for Economic Affairs (1989-92), and Administrator of the Economics and Statistics Administration (1990-92). During this period, Darby began his association with the NBER and was a Visiting Fellow at the Hoover Institution at Stanford.

Professor Darby is the widely cited author of eight books and monographs and numerous other professional publications. He also serves or served as a member of the editorial boards of the American Economic Review, Contemporary Policy Issues, Contemporary Economic Policy, and International Reports.

Minoo Dastoor
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Dr. Minoo Dastoor is the senior advisor to the Associate Administrator, Office of Aerospace Technology at NASA Headquarters in Washington, D.C. A member of the senior staff at Caltech's Jet Propulsion Laboratory, he is currently on a special assignment at NASA to develop and coordinate the Agency's Nano/Bio Technology Plan. A central feature of the Plan is to advance technologies that exploit the huge potential resulting from the convergence between nanotechnology, biology and information systems. The

Plan focuses on three areas: 1) nanomaterials, 2) nanoelectronics and information technology, and 3) sensors and microspacecrafts. The goal of the Plan is to provide the capabilities anticipated for future space mission and advanced aeronautic applications. Emphasis is on a dramatic reduction in size per mass, and an increase in strength (as well as intelligence) per mass, tailored specifically for the unique NASA needs; i.e. autonomous performance at ultra low power levels and in the hostile space environment. Dr. Dastoor received his Ph.D. in Microbiology and Immunology from the UCLA School of Medicine.

James R. Heath
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James R. Heath received a B.Sc. degree in chemistry from Baylor University in 1984, and a Ph.D. degree in chemistry from Rice University in 1988, where he studied in the group of Richard E. Smalley. Heath was a Miller Postdoctoral Fellow at UC Berkeley from 1988-91, where he worked in the laboratory of Richard J. Saykally. He was a research staff member at the IBM T.J. Watson Research Labs. in Yorktown Heights, New York from 1991-94. In 1994, he left IBM to join the Department of Chemistry and Biochemistry at UCLA. He was promoted to tenure in 1996, and to Full Professor in 1997. He is currently the scientific director of the California NanoSystems Institute (CNSI), which was formed by California's Governor Grey Davis in December 2000. Heath was a David and Lucile Packard Fellow (1994-1999), and an Alfred P. Sloan Fellow (1997). He is a Fellow of the American Physical Society, and has received the Jules Springer Award in Applied Physics (2000); the Feynman Prize (2000); and the Sackler Prize in the Physical Sciences (2001). Heath's research interests focus on 'artificial' quantum dot solids and quantum phase transitions in those solids, molecular electronics architecture, devices, and circuitry, and the spectroscopy and imaging of transmembrane proteins in physiological environments.

Michael J. Heller, Ph.D.
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Dr. Heller is a founder of the company and has served as its Chief Technical Officer since September 1993. In November 1991, Dr. Heller co-founded Nanogen's former parent company, Nanotronics, and since that time has served as Nanotronics' Vice President of Research. Dr. Heller co-founded and served as President and Chief Operating Officer of Integrated DNA Technologies from 1987 to 1989, and from 1984 to 1987 served as Director of Molecular Biology for Molecular Biosystems, Inc. Prior to 1984, he served as Supervisor of DNA Technology and Molecular Biology for Standard Oil Company. Dr. Heller received a Ph.D. in Biochemistry from Colorado State University.

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Professor Hu's research is focused on electronics and photonics: high-resolution fabrication techniques for semiconductor device structures, process-related materials damage, contact/interface studies, superconductivity. Before joining UCSB in 1984, Professor Hu worked at AT&T Bell Laboratories, developing microfabrication and nanofabrication techniques to facilitate the study of superconducting and semiconducting devices and circuits. She has continued those research themes at UCSB, through a variety of collaborative efforts, examining processes critical for the fabrication and operation of superconducting, electronic and optical devices. In particular, she has focused on ion-assisted chemical etching techniques having high spatial resolution, photo-driven processing tuned to the unique optical properties of the materials, and passivation treatments to enhance optical and electrical properties of structures at submicron dimensions. She has studied the formation of high quality, heterogeneous interfaces, such as those between semiconductors and superconductors, oxide and semiconductor, or two non lattice-matched semiconductors. She is currently serving as Director of QUEST, the NSF Science and Technology Center for Quantized Electronic Structures. She as well directs Nanotech, the UCSB component of the NSF National Nanofabrication Users Network. She has served as Vice Chair (1989-92), and subsequently Chair (1992-94) of the ECE Department. Professor Hu received her Ph.D. from Columbia University. She received the Tau Beta Pi Outstanding Faculty Award in ECE for 1989-90. Professor Hu is a Fellow of the APS and IEEE. In 1995, she was awarded an honorary Doctor of Engineering from Glasgow University.

Bruce E. Koel

Professor of Chemistry and Materials Science
Seaver Science Center, SSC 606
920 W. 37th Street, University Park
Los Angeles, CA 90089-0482

Bruce E. Koel is Professor of the Department of Chemistry and Adjunct Professor of Materials Science at the University of Southern California, Los Angeles, CA. He received B.S. and M.S. degrees in Chemistry from Emporia State University and obtained his Ph.D. in Chemistry from the University of Texas at Austin, where he began his work on surface chemistry. He was a Miller Postdoctoral Fellow at the University of California at Berkeley.

From 1983 until his promotion with tenure in 1989, he was an Assistant and Associate Professor of Chemistry and Fellow of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado at Boulder. There, awards included a Dreyfus Foundation Grant for New Faculty and an Exxon Education Foundation Award. In 1990, he moved to USC and was promoted to Professor of Chemistry in 1993. At USC, he was awarded an Alfred P. Sloan Research Fellowship, given Union Carbide Innovation Research Awards, and named to several Who's Who lists. He is a Fellow of the APS and AVS. His professional services include being Chairman of the Department of Chemistry at USC, Chairman of the AVS Surface Sci. Division, and membership on the Editorial Advisory Board of Langmuir. In 1993 he established a new Gordon Conference entitled "Chemical Reactions at Surfaces", and he was Vice-Chair in 1995 and Chair in 1997 for this Conference. An author of over 170 published papers, including several review articles and book chapters, he has given over 20 invited lectures at national and international scientific meetings during the past 5 years. His research interests include the structure and bonding of reactive molecules on surfaces, chemical modification of surface properties, and molecular robotics.

Martha A. Krebs
Director, California NanoSystems Institute (CNSI)
Associate Vice Chancellor for Research
University of California, Los Angeles (UCLA)
Box 957151
Los Angeles, CA 90095-7151

Dr. Martha Krebs is the Institute Director of the newly established California NanoSystems Institute (CNSI). She is responsible for the overall leadership, strategic direction and administration of the Institute. The Institute is a partnership between UCLA and UC Santa Barbara and carries out its work on both campuses. The Institute will focus on the understanding and design of nanostructures and their integration into complex systems with new properties beyond those already found in nature. In partnership with industry, the Institute will create new technologies and the next generation of scientists and engineers for the information, medical and manufacturing sectors.

Prior to joining the CNSI, Dr. Krebs was a senior Fellow at the Institute for Defense Analysis, where she led studies in R&D management, planning and budgeting. From 1993 to 2000, Dr. Krebs served as Assistant Secretary and Director of the Office of Science at the U.S. Department of Energy, responsible for the $3 billion basic research program that underlay the Department's energy, environmental and national security missions. She also had the statutory responsibility for advising the Secretary on the broad R&D portfolio of the Department and the institutional health of its National Laboratories. During her tenure, she built international collaborations in particle physics, strengthened interagency collaborations for human genome sequencing, synchrotron radiation and global climate research, and oversaw the advocacy and successful construction of eight major scientific user facilities. She served on the National Science and Technology Council's Interagency Committee on Science and its Committee on the Environment.

From 1983-1993, she served as an Associate Director for Planning and Development at the DOE's Lawrence Berkeley National Laboratory, where she was responsible for strategic planning for research and facilities, Laboratory technology transfer, and science education and outreach. From 1977-1983, she served on the House Committee on Science first as a Professional Staff Member and then as Subcommittee Staff Director, responsible for authorizing DOE non-nuclear energy technologies and energy science programs.

She received her Bachelor's degree and Ph.D. in Physics from the Catholic University of America. She is a member of Phi Beta Kappa, a Fellow of the American Physical Society, a Fellow of the American Association for the Advancement of Science, and a Fellow of the Association of Women in Science. She is a member of the National Academy Committee on Scientific and Engineering Personnel and the Navy Research Advisory Committee. She is married to Philip E. Coyle, III and has four children.

Michael Krieger, Ph.D., J.D.
Partner
Krieger & Nunziato LLP

Michael Krieger is a Los Angeles attorney whose practice is devoted to intellectual property and related business law for information and other high technology development, acquisition, licensing, and services. This focus includes strategic counseling, litigation strategy and preventive methods to exploit and secure content, inventions and other intellectual property. His clients range from start-ups to industry leaders, as well as government entities, the United Nations, and several international web-based initiatives. He has also served as an expert witness in technology litigation.

Holding degrees in mathematics (B.S., Caltech; Ph.D., UCLA) and law (J.D., UCLA), Mr. Krieger was a member of the MIT mathematics and UCLA Computer Science faculties as well as Fulbright Scholar, Computer Science (Brazil) prior to practicing law. With this technical background, he has long been involved with cutting edge issues at the interface of new technology and intellectual property law: he was among the first to comment on public key encryption policy (1978), and more recently has been involved with trademark/domain name conflicts, the Internet governance "wars," and the "open source" software business paradigm. He served as private advisor to Dr. Jon Postel while the late Internet pioneer/"czar" implemented the U.S. Government's mandate to privatize Internet administration.

Mr. Krieger serves on the Executive Committee of the California Bar's Intellectual Property Section and was Editor-in-Chief of its journal, "New Matter." He is a board member of several organizations supporting new venture development and teaches Entrepreneurship for UCLA's Computer Science Department. As a frequent speaker and author on intellectual property and related topics, Mr. Krieger has developed courses and conference programs for universities; the Software Publisher's Association, legal groups and other "IP consumers." He organized and chaired the 1988 International Conference on Computers and Law, participated in the Computer Law Delegation to China/Japan, and chaired/organized "Essentials of Technology Transfer" in 1999. Formerly with the venerable Bronson, Bronson & McKinnon until its dissolution, Mr. Krieger is a partner of Krieger & Nunziato LLP.

Philip J. Kuekes
Hewlett-Packard Laboratories
Quantum Science Research
Hewlett-Packard Laboratories
Palo Alto, California

Philip J. Kuekes is a member of the technical staff at Hewlett-Packard Laboratories in Palo Alto, California. He got his BS in Physics from Yale University in1969. He was co-designer of the first commercial array processor at Raytheon Computer (1970-71). This machine, the first low cost implementation of the newly discovered (1965) Fast Fourier Transform, was used extensively for seismic exploration in the 1970s.He was Project Engineer at Ling Electronics (1972-74) responsible for designing the Ling Array Processor, a state of the art array processor used by the Naval Research Laboratories for acoustic vibration testing of satellites. He formed a consulting business, Kuekes Engineering (1975-1979), to design hardware and microcode for highly pipelined systems.

Joe Lichtenhan
President
Hybrid Plastics

Dr. Joe Lichtenhan is Co-founder of Hybrid Plastics™ and serves as President, and Chief Executive Officer and Chairman of the Board. He is a pioneer and world authority in the field of Nanostructured™ Chemicals. His insights into their applications launched the company and the commercialization efforts for the technology. Prior to starting Hybrid Plastics™, he served for seven years as a Technical and Business Area Director for the Polymeric Component Applications Program at the Air Force Research Laboratory. As CEO and COB, Dr. Lichtenhan is responsible for strategic planning and the corporate governance of Hybrid Plastics. He received his BS from Kansas State University and a Ph.D. from the University of California at Irvine. His entrepreneurial activities started at the age twelve and he has actively participated in a number of sole-proprietorships including the cofounding of a national mail order company. He also currently serves on the Advisory Board for the Advanced Technology Program at the U.S. Department of Commerce's National Institute of Standards and Technology (NIST).

Bruce P. Mehlman
Assistant Secretary for Technology Policy
Technology Administration
U.S. Department of Commerce
Washington, DC 20230

Bruce was nominated as Assistant Secretary for Technology Policy by the President on April 30, 2001, and was confirmed by the U.S. Senate on May 25, 2001. As Assistant Secretary, Bruce leads the Office of Technology Policy. Prior to joining the Department of Commerce, Bruce served as Telecommunications Policy Counsel for Cisco Systems, Inc. At Cisco, Bruce worked with public policy leaders and technologists throughout the information technology community on issues of broadband deployment wireless networking, e-commerce strategies, and Internet policy.

Before joining Cisco, Bruce served as Policy Director and General Counsel at the House Republican Conference, the House of Representatives' leadership office headed by Oklahoma Congressman J.C. Watts, Jr. At the Conference, Bruce worked with leadership to help pass Y2K and China trade legislation, while organizing high tech education and outreach efforts for senior leadership and committee staff. Bruce formerly served as General Counsel of the National Republican Congressional Committee under Chairmen Bill Paxon (NY) and John Linder (GA). Before that Bruce worked as a litigation attorney in the Washington, D.C. law firm of Wiley, Rein & Fielding. Bruce received his B.A. from Princeton University and his J.D. from the University of Virginia School of Law.

James S. Murday
Superintendent
Chemistry Division
National Research Laboratory

Dr. James S. Murday received a B.S. in Physics from Case Western Reserve in 1964, and a Ph.D. in Solid State Physics from Cornell in 1970. He joined the Naval Research Laboratory (NRL) in 1970 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. He is a member of the American Vacuum Society (AVS), the American Physical Society, the American Chemical Society and the Materials Research Society. For the AVS, he has served as trustee for 1981-1984, director for 1986-1988, representative to the American Institute of Physics Governing Board 1986-1992, president for 1991-93, and representative to the Federation of Materials Societies. Under his direction, both the AVS and the International Union for Vacuum Science, Technology and Applications have created a Nanometer Science/Technology Division. He is Executive Secretary to the National Science and Technology Council's Subcommittee on Nanometer Science Engineering and Technology (NSET) and Director of the National Nanotechnology Coordinating Office. His personal research interests include interface analysis, surface modification technology and science/technology of nanometer structures.

Barbara J. Nelson
Dean
UCLA School of Public Policy and Social Research
3250 Public Policy Building Box 951656
Los Angeles, CA 90095-1656

Barbara J. Nelson was named the first permanent dean of the UCLA School of Public Policy and Social Research on November 1, 1996. Prior to her appointment as dean and professor of policy studies, she was vice president and distinguished professor of public policy at Radcliffe College where her portfolio included academic programs and strategic planning.

Dr. Nelson's fields of expertise include social and economic policies in industrialized nations, organizational theory and behavior, and social movements. The author of four books and more than 50 articles and book chapters, Nelson and co-author Najma Chowdhury won the 1995 Victoria Schuck Award for *Women and Politics Worldwide*, bestowed by the American Political Science Association for the best book in the field of women and politics. In 1989, Dr. Nelson and historian Sara Evans won the Policy Studies Organizations' prize for the best book in the field of policy analysis for *Wage Justice: Comparable Worth and the Paradox of Technocratic Reform*. Nelson is also the author of *Making an Issue of Child Abuse: Political Agenda Setting for Social Problems* (1984) and *American Women and Politics* (1984). Dean Nelson is currently writing two books: *Solving Impossible Problems: Organizations of Concord and the Renewal of Democratic Life*, and *Leadership for the Twenty-First Century: Inclusion and Change*.

Dean Nelson has made major contributions to policymaking and civic life in the United States and abroad. She was a founding member of the Minnesota Supreme Court's Task Force on Gender Equity in the Courts. She consulted with the Swedish government on its Parliamentary Commission on Power and Democracy, and has worked with several United Nations agencies on questions of economic development and political participation. Nelson is a member of the Board of Trustees of the Center for the New West, and a former board member of Radcliffe College, the National Council for Research on Women, and the American Political Science Association.

Before her appointment at Radcliffe, Barbara Nelson served on the faculties of the Woodrow Wilson School of Public and International Affairs at Princeton University and the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota, where she served as director of its Center on Women and Public Policy. She earned her B.A., M.A., and Ph.D. in political science at Ohio State University.

Michael Partsch
Versant Ventures
450 Newport Center Drive, Suite 380
Newport Beach, CA 92660

Michael has worked in the biotech industry for most of the decade. As a research biochemist, he was a founding member of Neose Technologies, a company, which was incorporated in 1990 and went public in 1996 (NASDAQ:NTEC). There, he performed synthesis and purification work on the company's novel anti-infective compounds. While in business school, Mike spent time as an associate at the CEO Venture Fund, where he assisted in the management and oversight of portfolio biotech firms. He has also served in a consulting capacity for Prolx Pharmaceuticals, Inc. Mike received a bachelor's degree in Biology with a minor in Chemistry from the University of Pennsylvania, and holds an MBA degree from Carnegie Mellon University with dual concentrations in Finance and Entrepreneurship. Before joining Versant, Michael worked for two years as a Kauffman Fellow at EDF Ventures in Ann Arbor, Michigan, where he focused on early-stage Healthcare investments.

Brian M. Pierce
Engineering Fellow and Manager of Advanced RF Technologies Department,
Microwave Center, Raytheon Electronic Systems,
El Segundo, CA

Dr. Pierce has been working for twenty years on the development of advanced and emerging technologies for radar and electro-optical sensor applications. He started his industrial career with Hughes Aircraft Company in 1983, to work on a project related to molecular electronics. Subsequent to this project, he became the Principal Investigator of a Hughes Aircraft program concerning device applications of nonlinear optical organic crystals and polymers, as well as contributing to other R&D efforts. Dr. Pierce has been the program manager for a number of technology development programs that include: engineering the microwave dielectric properties of ion-conducting materials, electron-conducting polymers, and polar dielectrics for lightweight Radar Absorbing Materials (RAM); laser eye protection technologies; Global Broadcast Service (GBS) airborne receive antenna; nonlinear magnetic materials for passive microwave device applications; nonlinear dielectric materials for electronic scanned antenna applications, and most recently, RF MEMS technologies for electronically scanned antennas. He is currently the Manager of the Advanced RF Technologies Department at the Microwave Center in El Segundo, CA, and helps develop both military and commercial technology opportunities for Raytheon Electronic Systems.

Dr. Pierce was a Guest Professor for the Danish Technical University in Lyngby, Denmark. He graduated *summa cum laude* from UC Riverside. His M.S. and Ph.D. in Chemistry are also from UC Riverside. He is the author or co-author of over 30 papers and reports in the fields of nonlinear-optical phenomena, solid state physics, two-photon spectroscopy, molecular orbital theory, vibrational normal mode analysis, energy transfer, molecular dynamics and environmental technology and is responsible for 14 U.S. patents.

Arati Prabhakar
Venture Partner
U.S. Venture Partners
2180 Sand Hill Road, Suite 300
Menlo Park, CA 94025

Dr. Arati Prabhakar who joined U.S. Venture Partners as a venture partner in February 2001, was a program manager and then director of the Microelectronics Technology Office at the Defense Advanced Research Projects Agency from 1986 to 1993. Through her DARPA investments, she worked with over 300 companies, universities, and other labs to pursue breakthrough technologies in semiconductor manufacturing, imaging, optoelectronics, and nanoelectronics. In 1993, President Clinton appointed Arati as the Director of the National Institute of Standards and Technology (NIST), where she led the 3000-person staff until 1997. At NIST, she co-invested with companies in R&D in areas ranging from healthcare information infrastructure to composite materials to DNA diagnostics. At DARPA and NIST, Arati and her team funded the people and the technologies that went on to build a number of companies with multi-billion-dollar valuations.

In 1997, Arati joined Raychem Corporation as senior vice president and chief technology officer. She served as a member of the CEO's executive team and established a process technology program that significantly improved productivity. She was subsequently vice president and then president of Interval Research Corporation, which she joined in 1998. Arati focused Interval on opportunities in broadband technologies and applications, launching new companies and licensing opportunities. Arati received her B.S. in Electrical Engineering from Texas Tech University. She received a M.S. in Electrical Engineering and a Ph.D. in Applied Physics from the California Institute of Technology. Arati began her career as a Congressional fellow at the Office of Technology Assessment. She is a Fellow of the Institute of Electrical and Electronics Engineers and of the IC2 Institute.

Stephen Quake, Ph.D.
Founder
Fluidigm Technology
7100 Shoreline Court South
San Francisco, CA 94080

Dr. Quake is a founder of the Fluidigm and a recognized pioneer in the fields of biophysics and molecular biology. He presently serves as an Associate Professor in the Department of Applied Physics at the California Institute of Technology. MIT Technology review magazine named Dr. Quake one of the "Top 10 innovators in emerging technology. Dr. Quake has received many scientific awards and honors, including the opportunity to participate in the N.A.E. Symposium for Frontiers in Science in 2000 and has been awarded the NSF "Career" award in 1997. He has also served on a variety of scientific committees, including the Biological Analysis Systems Expert Panel, MITRE, in 1999 and the organizing committee for the NAS Symposium for Frontiers in Science in 2001. Dr. Quake has published over 20 papers in the fields of microfluidics and biophysics. He holds a B.S. in Physics and M.S. in Mathematics from Stanford University and a Ph.D. in Theoretical Physics from Oxford University.

Joe Raguso
Deputy Secretary
California Technology, Trade and Commerce Agency
Division of Science, Technology and Innovation
801 "K" Street, Suite 1926
Sacramento, CA 95814

As Deputy Secretary of the California Technology, Trade & Commerce Agency's Division of Science, Technology and Innovation (DSTI), Joe establishes the agenda for the division, oversees the management of its programs and projects, and serves as an advisor to the Governor and the California Legislature on technology policy.

Before accepting his current appointment, Joe served as President and CEO of the San Diego Regional Technology Alliance (SDRTA). Joe has a wide range of experience in both the public and private science and technology sectors. Prior to his position with the SDRTA, Joe worked in the Office of Science and Technology Policy and Projects at University of California, San Diego (UCSD) where he developed strategic partnerships with private industry and Federal agencies to advance the research goals of UCSD.

Prior to coming to California, Joe served in the Clinton Administration as a Deputy Assistant Secretary of the Office of Technology Policy. His responsibilities included directing "Partnerships for a Competitive Economy"—a program that works to promote the role technology plays in economic growth and job creation, implementing the Administration's competitiveness policies, and developing Federal mechanisms to leverage state efforts to advance national science and technology goals.

In the private sector, Joe worked for IBM and Galileo Electro-Optics Corporation. His educational background includes a master's degree in Technology and Policy from Massachusetts Institute of Technology.

Mihail (Mike) C. Roco
Senior Advisor
National Science Foundation
4201 Wilson Blvd., Suite 525
Arlington, VA 22230

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 directs research opportunities in the mechanical and chemical processes, and coordinates the programs on academic liaison with industry (GOALI). Prior to joining National Science Foundation, 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).

Credited with credited 13 inventions, Dr. Roco has authored/co-authored numerous archival articles and other publications, and several books including "Slurry Flow: Theory and Practice" (Butterworth, 1991), "Particulate Two-phase Flow" (Butterworth, 1993) and "Nanostructure Science and Technology" (Kluwer Acad., 1999). He is a key architect of the National Nanotechnology Initiative, and coordinated the preparation of the National Science and

Technology Council reports on “Nanotechnology Research Directions” (NSTC, 1999) and “National Nanotechnology Initiative” (NSTC, 2000).

Dr. Roco is a Correspondent Member of the Swiss Academy of Engineering Sciences and a Fellow of the ASME. He was honored as recipient of the Carl Duisberg Award in Germany, “Burgers Professorship Award” in Netherlands and the “University Research Professorship” award in U.S., and more recently the “Engineer of the Year” (1999) by the U.S. National Society of Professional Engineers and NSF. He has been co-founder and Chair of the AIChE Particle Technology Forum, Associate Technical Editor for Journal of Fluids Engineering, and the Editor-in-chief of the Journal of Nanoparticle Research.

Rohit Shukla
President and CEO
The Los Angeles Regional Technology Alliance (larta)

Rohit K. Shukla is President and Chief Executive Officer of the Los Angeles Regional Technology Alliance (larta), a private nonprofit organization providing information, networking and direct business assistance to the technology and interactive community in Southern California. larta is a central point for assisting companies and policymakers in California in meeting the challenges of the New Economy. Prior to his current position, Rohit Shukla served as Director of Aerospace and High Technology Business at the Los Angeles Economic Development Corporation. He oversaw the first Federally funded “defense adjustment” program in the country.

Mr. Shukla has worked in high technology industry since 1983, first as an entrepreneur and founder of his own small company providing database and communications solutions and devices, and later as the Executive Director of The Presidents’ Roundtable, a mentor group of CEOs from defense and aerospace companies throughout the U.S. In October 1997, he was appointed by Los Angeles Mayor Richard Riordan to both the Board of Information Technology Commissioners (which he currently serves as Vice President) and a special blue ribbon task force on communications infrastructure for the City of Los Angeles. He has co-authored the City’s policy on “open access” and is currently involved as a regulator in the re-franchising process. Mr. Shukla holds a Masters in Economics and Politics from Cambridge University and a Masters in Communications Arts from Loyola Marymount University, Los Angeles.

Richmond A. Wolf
Associate Director
Office of Technology Transfer
California Institute of Technology
1200 E. California Blvd M/C 210-85
Pasadena, CA 91125

Dr. Rich Wolf is the Associate Director of the Office of Technology Transfer. He oversees the JPL patent portfolio and is responsible for licensing various technologies originating at JPL, as well as various information technologies developed at Caltech. Rich has co-founded and consulted a number of technology-based start-up companies. He is a graduate of Caltech, receiving his Ph.D. in Geology in 1997.

Eli Yablonovitch
Professor
UCLA Department of Electrical Engineering
66-147K Engr IV Box 951594
Los Angeles, CA 90095-1594

Dr. Eli Yablonovitch graduated with the Ph.D. degree in Applied Physics from Harvard University in 1972. He worked for two years at Bell Telephone Laboratories, and then became a professor of Applied Physics at Harvard. At the peak of the energy crisis in 1979, he joined Exxon to do research on photovoltaic solar energy. Then in 1984, he joined Bell Communications Research, where he was a Distinguished Member of Staff, and also Director of Solid-State Physics Research. In 1992 he joined the University of California, Los Angeles, where he is Professor of Electrical Engineering.

His work has covered a broad variety of topics: nonlinear optics, laser-plasma interaction, infrared laser chemistry, photovoltaic energy conversion, strained-quantum-well lasers, and chemical modification of semiconductor surfaces. Currently his main interests are in optoelectronics, high speed optical communications, high efficiency light-emitting diodes and nano-cavity lasers, photonic crystals at optical and microwave frequencies, quantum computing and quantum communication.

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Advisory for Monday, Sept. 10

UCLA to Host Business-Government Workshop on Nanotechnology Issues

WHAT: UCLA's California NanoSystems Institute will host a workshop on "Nanotechnology: Opportunity and Challenge for Industry." More than 150 business and academic leaders from Southern California will attend the workshop, which will address nanoscience research being conducted at U.S. universities. It is the first of several to be held in the next 18 months throughout the United States.

WHO: Bruce Mehlman, assistant secretary for technology policy in the U.S. Department of Commerce, will give the opening remarks.

WHEN: 8:30 a.m. to 5 p.m., Monday, Sept. 10.

WHERE: UCLA's James West Alumni Center, 325 Westwood Plaza.

BACKGROUND: The California NanoSystems Institute, known as CNSI, is a joint enterprise of UCLA and UC Santa Barbara. CNSI was established last year to facilitate nanotechnology development in information, biomedical and manufacturing industries in California. In 2000 Gov. Gray Davis named CNSI as one of three research efforts statewide to receive $100 million in state support to help propel the future of the California economy.

The Nanotechnology Workshop is being co-sponsored by the UCLA School of Public Policy and Social Research in conjunction with the U.S. Department of Commerce; Federal Aviation Administration; the National Nanotechnology Coordinating Office, National Science Foundation; and industry partner, the Los Angeles Regional Technology Alliance. Workshop panel discussions and break-out sessions will be conducted by leaders of large and small California technology companies, academic researchers, and Federal and state policymakers. The UCLA conference will focus on the importance of nanotechnology to three areas: aerospace, information technology/electronics and biotechnology issues.

The recommendations of the UCLA workshop and subsequent regional meetings will be used to inform and guide Federal and state policymakers. Nanotechnology research is supported largely by a $500 million Federal research commitment, begun in the previous administration and continued, with increased funding proposed, by President Bush.

CONTACT: Stan Paul, director of communications, UCLA School of Public Policy and Social Research, (310) 206-8966.

-UCLA-

WORKSHOP AGENDA

Nanotechnology: Opportunity and Challenge for Industry

Monday, September 10, 2001
University of California, Los Angeles

7:30 a.m.	Registration	
8:30 a.m.	Welcome and Review of Agenda	Martha A. Krebs, Director, California NanoSystems Institute
	Welcome	Barbara J. Nelson, Dean UCLA School of Public Policy and Social Research
	Opening remarks	Bruce P. Mehlman, Assistant Secretary for Technology Policy U.S. Department of Commerce
9:10 a.m.	**Opening Presentations**	
	Nanoscience and Technology in California	Joe Raguso, Deputy Secretary California Technology, Trade and Commerce Agency's Division of
Science,		Technology and Innovation
	The Science of NanoSystems	James R. Heath, Scientific Director California NanoSystems Institute
9:40 a.m.	**Plenary Session**	Moderator: Martha A. Krebs, CNSI Brian M. Pierce, Raytheon Steve Quake, Caltech/Fluidigm Michael R. Darby, UCLA Joel Balbien, Smart Tech Mihail (Mike) C. Roco, National Science Foundation
11:15 a.m.	Break	

11:30 a.m. **Concurrent Sessions**

Large Conference Room

Session 1 – Bioscience
Moderator: Martha A. Krebs, UCLA
Michael J. Heller, Nanogen
Scott Broadley, Broadley-James
Scott R. Carter, Caltech
Michael Partsch, Versant Ventures
Mihail (Mike) C. Roco,
National Science Foundation

Founders' Room

Session 2 – Information Technology
Moderator: Michael Krieger, Krieger &
Nunziato LLP
Philip Kuekes, Hewlett Packard
Eli Yablonovitch, UCLA
Bruce E. Koel, USC
Arati Prabhakar, U.S. Venture Partners
James S. Murday, NRL

Presidents' Board Room

Session 3 – Aerospace

Moderator: Rohit Shukla, larta
John H. Belk, Boeing
Joe Lichtenhan, Hybrid Plastics
Richmond A. Wolf, Caltech
Joel Balbien, Smart Technology

Ventures

Minoo Dastoor, NASA

12:30 p.m. Conference Room Patio

Lunch
Welcome Remarks
Chancellor Albert Carnesale, UCLA

1:45 p.m. **Concurrent Sessions**

Large Conference Room

Session 1 – Bioscience
Moderator: Martha A. Krebs, UCLA
Michael J. Heller, Nanogen
Scott Broadley, Broadley-James
Scott R. Carter, Caltech
Michael Partsch, Versant Ventures
Mihail (Mike) C. Roco,
National Science Foundation

	Founders’ Room		<u>Session 2 – Information Technology</u> Moderator: Michael Krieger, Krieger & Nunziato LLP Philip J. Kuekes, Hewlett Packard Eli Yablonovitch, UCLA Bruce E. Koel, USC Arati Prabhakar, U.S. Venture Partners James S. Murday, NRL
	Presidents’ Board Room		<u>Session 3 – Aerospace</u> Moderator: Rohit Shukla, larta John H. Belk, Boeing Joe Lichtenhan, Hybrid Plastics Richmond A. Wolf, Caltech Joel Balbien, Smart Technology
Ventures			
			Minoo Dastoor, NASA
3:30 p.m.			Break
3:45 p.m.			Reports and Outcomes
4:30			Wrap-up Discussion and Conclusions
5 p.m.			Close