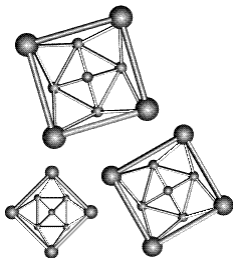

NANOTECHNOLOGY:
THE NEXT GREAT WAVE OF INNOVATION

White Paper
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Prepared by the
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NANOTECHNOLOGY:
THE NEXT GREAT WAVE OF INNOVATION
A White Paper

Introduction

According to the National Science Foundation, nanotechnology is projected to be a $1 trillion market within the next twelve years. Silicon Valley has long been known as a technological leader, and it only seems natural to assume that the Bay Area will garner a large portion of that market. However, does Silicon Valley have what it takes to serve as the foundation for the next technological innovation?

This white paper will provide a snapshot of nanotechnology in Silicon Valley, as presented at the recent Bay Area Nanotechnology Forum held at the NASA Ames Research Center. It will explore what nanotechnology is and what it isn't, and outline practical applications for nanotechnology as well as recent technological advancement and successes. It will look at the current state of nanotechnology funding throughout the world and existing legislation to develop and support nanotechnology's huge appetite for infrastructure. This paper will also discuss the key players who were in attendance at the Forum who are making nanotechnology happen—government labs, educational institutions, and corporate facilities. Finally, it will discuss the future direction Silicon Valley must take to achieve the goal of becoming the world leader in nanotechnology research, development, and commercialization.

Indications point to nanotechnology becoming an important, all-encompassing technology that will affect all sectors of the global economy, and Silicon Valley, if it wants to retain its position of dominance, must take the world leadership role in its development. If not, it could lose out on a technology that has the potential to deliver significant economic and community benefits. As it currently stands, Silicon Valley has already lost the competition for previous nanotechnology funding to other, less infrastructure-rich areas such as Austin, Boston, and Albany, New York.

The Technology

Definition

nano- *(**NAH**-noh)*

> *Prefix representing 10^{-9} (0.000000001) or one-billionth of the unit adjoined (e.g., a nanometer is a unit of length equal to one-billionth of a meter, which is roughly 10,000 times smaller than the diameter of a human hair)*

nano•tech•nol•o•gy *(NAH-noh-tek-**NAWL**-uh-jee)*

n. 1. *technology based on the manipulation of individual atoms and molecules to build structures to complex, atomic specifications [K. Eric Drexler, Engines of Creation];*

2. *the creation of useful, functional materials and devices at the nanoscale. [Meyya Meyyappan, Bay Area Nanotechnology Forum];*

3. *the creation, use, or manipulation of matter on the nanoscale to take advantage of properties that reign at that scale. [Small Times Magazine]*

According to NASA Ames Research Center, nanotechnology is defined as the creation of functional materials, devices, and systems through control of matter in the range of from one-tenth to one hundred nanometers (0.1–100nm), and exploitation of novel phenomena and properties at this scale. This technology is enabling a scientific and technical revolution based upon the ability to systematically organize and manipulate matter at the atomic scale. Product development and manufacturing will also benefit through molecular engineering or molecular manufacturing.

The term "nanotechnology" was coined in 1976 by Norio Taniguchi, a Tokyo Science University professor, and made popular by K. Eric Drexler in *Engines of Creation*, his seminal work on the topic published in 1986. As the field has evolved over the past 20 years, it has undergone a refinement in regard to the particular technologies that it encapsulates. The most recent revisions—those also least assimilated by the media and nonscientific audiences—place emphasis on "useful" and "functional" and the condition that the technology "take advantage of" elements' nanoscale properties.

Changes made at the atomic level create significant changes in the physical, chemical, biological, mechanical, and/or electrical properties of individual elements. In an example provided by Dr. Meyyappan of NASA Ames, gold in its metallic state melts at 1064° Fahrenheit. When this substance is manipulated at the atomic scale, the melting point drops dramatically. In fact, a particle of gold roughly 1.75 nanometers (nm) in size has a melting point of around 500°F. In and of itself, this atomic act remains fixed within the realm of chemistry and will only be considered nanotechnological if the process results in a "useful and functional material or device."

Real-World Applications

There is significant interest and a concerted effort put forth from all sectors of industry towards the development of technology based on the nanoscale. As an enabling technology, nanotechnology is expected to have an impact on a wide range of applications in industry including materials and manufacturing, nanoelectronics and computing, health and medicine (including biopharmaceuticals), environment and energy, automotive, national security, and aeronautics and space exploration.

Materials and Manufacturing

Nanotechnology has the potential to transform materials and manufacturing, and research is driven by the need to improve functionality of materials. For example, there has been a significant amount of research directed at developing "self-healing" materials. Biological structures have the ability to reconstruct naturally. However, all manmade materials experience some form of failure—glass can crack, rubber can break down, etc. By applying nanotechnology to materials manufacturing, the self-healing that occurs in biological structures can potentially be simulated in manmade structures.

Nanoelectronics and Computing

In terms of electronics and computing, nanotechnology has the potential to have a big impact. Potential applications include the expansion of increasingly greater amounts of data storage on an increasingly smaller scale, and the synthesis of all components related to computer technology, including wiring and connecting. One specific example is a chip embedded in the wall of a structure that controls the operational demands of the homeowner or guest (e.g. with the flip of a switch, the color of the wall could change to fit the individual's choice).

Health and Medicine

The future of nanotech in the fields of health and medicine is far reaching. Anticipated advances include: effective and less expensive health care using remote and in-vivo devices; new formulations and routes for drug delivery; optimal drug usage; more durable, rejection-resistant artificial tissues and organs; and sensors for early detection and prevention. It is also anticipated that nanotechnology will allow for accelerated gene sequencing—from the Human Genome Project's 10 years per person to 10 minutes, allowing for personalized medicine. This would allow treatment with drugs made specifically for each individual patient.

Environment and Energy

The practical impacts of nanotechnology in the environment and energy arena can be found in the development of increasingly efficient technologies. For example, with nanotechnology as an enabling technology, fuel consumption rates for automobiles and airplanes will improve, and lighting will become more efficient. Standard light bulbs currently only yield a seven to eight percent conversion rate, meaning that more than 90 percent of the energy going into a light bulb is wasted. Nanotechnology has the potential to change that.

Automotive

The automotive electronics industry is projected to grow to $30 billion by 2005, and the pressure to keep the cost of devices low is tremendous. Through the enabling technology of nanotech, future systems of automobiles may host the ability to electronically avoid collisions, as well as host some form of brake-by-wire, steer-by-wire systems (slowing the car and guiding electrically instead of manually), and allow for the development of sensory systems when new fuel sources become common.

National Security

Nanotechnology is also anticipated to yield promising returns for national security. One of the primary challenges of maintaining effective national security is rooted in the need for streamlined and protected communication centers, communication lines, and data storage. Increasing the efficiency of these areas through nanoelectronics will help to improve the gathering of information, as well as the distribution of information.

Other nanotech-driven defense applications currently underway include: the collection, transmission, and protection of information; high-performance, high-strength, lightweight military platforms; chemical, biological, and nuclear sensors for homeland protection; nanomechanical and micromechanical devices for control of nuclear and other defense systems; virtual reality systems based on nanoelectronics for effective training; and increased use of automation and robotics.

Aeronautics and Space Exploration

There is tremendous need to decrease the weight of all equipment related to aeronautics and exploration; this is within the scope of nanotechnology's enabling capability. One of the greatest barriers to the rapid growth of space exploration is cost. The cost of sending spacecraft sent into Earth orbit is roughly $10,000 per pound and sending craft to Mars is roughly $100,000 per pound.

Ultimately, regardless of the efficiencies enabled by nanotechnology, products offered to the public must still be cost effective. In order for nanotechnology to be a valuable resource to others, the products created by this technology must not only be more efficient but affordable to the average customer.

Existing Legislation

Background

The anticipated returns of nanotechnology continue to fuel the support of President Bush and policymakers across the nation. Additionally, the potential that the U.S. could fall behind Japan, China, and Europe in the development of nanotechnology is a concern of policymakers, scientists, and business leaders alike. According to the National Science Foundation, it is estimated that by the year 2015, the international market for nanotechnology products and services could total $1 trillion. Both factors—the potential for nanotechnology to yield significant benefits and the national interest in maintaining global competitiveness—can be considered largely responsible for the genesis of a federal nanotechnology strategy and the continued support of the government toward nanotechnology.

In 1996, a federal interagency work group was formed to set up and define a national nanotechnology strategy. In September 1998, this informal group was officially designated as the Interagency Working Group on Nanotechnology (IWGN) under the National Science and Technology Council. The IWGN has laid the groundwork for the current National Nanotechnology Initiative (NNI), which has been in effect since 2001. The NNI is a collaborative initiative of 13 federal agencies and is representative of continued federal support for the growth of this technology.

House Resolution 766

As the existence of the National Nanotechnology Initiative indicates, a collaborative effort already exists on the part of universities, government, organizations, businesses, and other entities toward a nanotechnology revolution. Nonetheless, continued federal funding is key to actualizing this goal.

House Resolution 766 (The Nanotechnology Research and Development Act of 2003), co-sponsored by U.S. Representatives Mike Honda (D-CA) and Sherwood Boehlert (R-NY), Chairman of the House Science Committee, exemplifies the most recent proactive efforts toward nanotechnology by government. According to the sponsors of H.R. 766, federal support for nanotechnology is necessary if current efforts are to move beyond the research stage. Representative Honda stated at the Bay Area Nanotechnology Forum that,"In today's business

climate, the demand for short-term returns prevents companies from investing in long-term, high-risk work, which advancing nanotechnology will require. Therefore, the federal government is one of the few investors that can take a long-term view and make the sustained investments that are required to bring the field to maturity." A concerted effort has been made to educate interested audiences about the need for sustained sources of investment to ensure that nanotechnology development moves beyond the initiation stage to production.

How does House Resolution 766 come into play in sustaining U.S. research on nanotechnology? Essentially, the bill authorizes five federal agencies participating in the National Nanotechnology Initiative to spend almost $2.4 billion over the next three years on nanotechnology research and development. These agencies include the National Science Foundation, the Department of Energy, the National Aeronautics and Space Administration, the Commerce Department's National Institute of Standards and Technology, and the Environmental Protection Agency. H.R. 766 increases funding to the National Science Foundation and Department of Energy over the levels recommended by President Bush for Fiscal Year 2004. In addition to authorizing funding, the bill also makes changes to the organization of the federal R&D effort to introduce more oversight.

House Resolution 766 is notably on a fast track. In May 2003, the bill passed out of the House of Representatives by a vote of 405 to 19. This was just three months after its introduction in a partisan House by Congressman Honda, a freshman minority delegate. It is anticipated that the resolution will be approved by the Senate once Congress reconvenes.

Funding

As noted, nanotechnology is projected to be a $1 trillion market by 2015. In order to be in position to benefit from this projected market, more than 30 countries have launched nanotechnology research and development programs. How is Silicon Valley positioned compared to the rest of the world?

International

There are three primary international locations that are funding nanotechnology R&D programs —Western Europe, the People's Republic of China, and Japan. The collaboration between European countries is further assisted financially through European Union (EU) nanotechnology allocations. In 2002, the EU allocated as much as €3.3 billion ($3.6 billion US) for nanotechnology research over the next four years through the EU's Sixth Framework for R&D development. As with Western Europe, Japan has nanotechnology programs that are backed by the government, and are a collaboration between academic institutions and industrial groups. Funding in Japan is also large—government funding increased from $120 million US in 1997 to an estimated over $1 billion in 2003. China also has a large and growing nanotechnology program with the largest expenditure of any country in purchasing power parity terms.

National

Perhaps because of the pressure to successfully compete against Western Europe, China, and Japan in the nanotechnology race, the United States is poised to soon hit the $1 billion mark in nanotechnology R&D spending. Historically, the United States has lagged behind its competitors in terms of nanotechnology funding. For example, in 1997 both Western Europe and Japan spent around $126 million, whereas the US spent only $70 million on nanotechnology R&D. However, the President's 2004 Budget will provide $847 million for the National Nanotechnology Initiative, which is a 9.5 percent increase over 2003. Although this spending increase is substantial, it is unclear whether or not Silicon Valley is in position to effectively advocate for funds. Fortunately for the U.S., nanotechnology development is getting bipartisan support from Congress. In years past, virtually all federal funding has gone to non-Silicon Valley locations. For example, in 2001 the National Science Foundation awarded a total of $65 million over five years to fund six nanotech science and engineering centers in New York, Massachusetts,

Illinois and Texas. Silicon Valley has the potential, though, to secure increased funding for nanotechnology R&D through regional collaboration and interaction with federal funding agencies spearheaded by the Northern California Nanotechnology Initiative (NCnano). As mentioned, Representative Honda has co-sponsored the Nanotechnology Research and Development Act, which authorizes $2.36 billion over the next three years for nanotechnology research and development programs. If the bill passes, it will be important for Silicon Valley leaders to be proactive in securing a substantial share of new resources.

The Region

Silicon Valley's Historic Success

California's Santa Clara Valley has always been recognized for the goods that it produces. Throughout the first half of the 20th century, the region was known as the Valley of Heart's Delight and was the tenth largest growing area in the country. Natives to the region may still remember the apricot and cherry orchards that stretched across the valley. Now known throughout the world as "Silicon Valley," the region owes its global stature to a handful of innovative individuals who put their faith in the future of technology and one university that had the foresight to invest in the intellectual capital of the region.

Silicon Valley's technological history originates with Lee deForest's invention of the Audion tube sound amplifier. In 1909, Stanford University President David Starr Jordan invested $500 in this amplifier, which proved to be instrumental in the evolution of electronics, and set the stage for Stanford's ongoing support of technology within the region.

Frederick Terman, the "Father of Silicon Valley," was a professor of electrical engineering at Stanford in the 1930s. Recognizing that many of his graduate students were leaving the area to work for East Coast companies, it was he who encouraged many of his brightest students, including William Hewlett and David Packard, to remain in Palo Alto and to start companies locally. Throughout World War II, Terman was key to generating federal investment both for Stanford University and for many of these local companies.

In the postwar growth of the 1950s, Stanford administrators recognized that they could lease university land to both generate income for the university and to develop local research parks that would be beneficial to all parties. In 1953, Varian Associates—founded by two recent Stanford graduate students—moved into the first building in the Stanford Industrial Park, followed soon after by Eastman Kodak, General Electric, and many others.

Throughout the Cold War, the federal government invested heavily in technology and the region continued to blossom. In 1956, Lockheed Aerospace Co. established residence in the Stanford Industrial Park and moved a year later to its current home in Sunnyvale. Within a matter of years, several other established organizations, including IBM, NASA, and Xerox, moved their key research departments to the region. Defense drove the first wave of Silicon Valley innovation.

Nobel Laureate Dr. William Shockley is credited with co-inventing the transistor and bringing silicon to Silicon Valley when he chose to return to Palo Alto to work on commercializing his semiconducting invention—the integrated circuit. His company, Shockley Transistor Laboratories, lured many of the brightest engineers to the Valley, and through various spin-offs over the years, resulted in the birth of Fairchild Semiconductor, Intel, Signetics (now Philips Semiconductors), National Semiconductors, and Advanced Micro Devices (AMD). It is the success of the semiconductor that drove the second wave of innovation and established Silicon Valley as the premier center of technology in the world.

Since 1946, when the first "computer," ENIAC (Electronic Numerical Integrator and Computer), was created in Pennsylvania, companies were driven to create faster, smaller, and cheaper computers using semiconductor technology. It was not until 1975, however, that Steve Wozniak and Steve Jobs, two Valley locals, created a home-built computer they called the Apple I. The following year, they created a more user-friendly computer and started Apple Computer, thus launching the personal computer revolution and the third wave of Valley innovation.

The Internet boom, founded on work dating back to 1964, became the most recent wave of Valley innovation when, in the early 1990s, former Stanford Professor and founder of Silicon Graphics, Jim Clark, hired Mark Andreesen, an academic from the University of Illinois, to found Netscape Communications in Mountain View. It was shortly after their development of Netscape Navigator, one of the leading browser applications, that Internet usage expanded exponentially, spawning a new age of information sharing and commerce that resulted in the "dot-com boom" of the late 1990s.

While the Valley continues to feel the effects of the economic correction resulting from unregulated growth of this "new economy," we can turn to the Valley's successful history of innovation, invention, ideas, and effective collaboration of all key stakeholders to provide direction for future growth and to foster development of the next wave of innovation.

Silicon Valley Infrastructure

Silicon Valley is a knowledge-based economy. The industries that drive this unique region are highly dependent upon cutting-edge businesses, world-class educational institutions, innovative research facilities, and the exceptionally skilled and knowledgeable workforce that is available locally. These regional resources and the degree of collaboration between them have fostered the Valley's unrivaled success of the past 60 years.

Silicon Valley has been the leader in global technology through its involvement with increasingly more complex waves of technological innovation since the federal investment in defense-related technology in World War II. From defense to the integrated circuit to the personal computer to the Internet, each wave has built upon earlier successes and resulted in great prosperity for Valley residents and for the region as a whole.

The world is now primed for the next great wave of innovation—nanotechnology—and Silicon Valley is well positioned to lead the world in the realms of research and commercialization of this enabling technology. As with preceding technological advances, nanotechnology will build upon breakthroughs in a variety of science and engineering fields, such as biology, chemistry, physics, electrical engineering, and materials engineering. Northern California, primarily Silicon Valley and the greater San Francisco Bay Area, already possesses the necessary infrastructure—including requisite leadership, knowledge, experience, physical space, and venture capital—involved with these related industries. The process of pulling together these existing resources in pursuit of establishing the region as a nanotechnological power is, as many regional experts believe, primarily a matter of bringing together the key stakeholders and presenting the region as a cohesive entity with one voice and one mission.

In its 2002 report entitled *Preparing for the Next Silicon Valley*, Joint Venture: Silicon Valley Network theorizes three potential outcomes to the region's involvement with the next wave of innovation:

1. *The wave could miss us.* The wave of innovation could pass us by because leaders in other regions provide a better habitat for companies developing and applying bio-, info-, and nanotechnologies to flourish. In the meantime, our economy would decline as innovative firms move out and other firms struggle to remain viable in established technologies and markets.

2. *The wave could roll over us.* Like the Internet boom, the next wave of innovation could happen here, but with negative consequences. If our residents are not prepared to participate, we would be forced to import thousands of new workers. If our communities are unable to manage the influx of people and the development pressures effectively, they would experience significant disruption.

3. *The wave could work for us.*This outcome is possible only if we understand and take the proper steps for what's coming, prepare our people and places for the next wave, and use it to create broadly shared prosperity and enhance our quality of life.

If the region is prepared—willing to learn from historical successes, to leverage existing resources, and to work together to establish itself as a future bastion of nanotechnology—there is every indication that Silicon Valley can become the world leader in nanotechnology research and commercialization and reap the benefits afforded that title.

Regional Stakeholders Participating in the Forum

Key participants in the Bay Area Nanotechnology Forum are highlighted below.

NASA Ames Research Center
Dr. G. Scott Hubbard, Director

Dr. Hubbard is the director of NASA Ames Research Center. NASA is involved in nanotechnology in part to help support their aeronautics and space programs. At the forum, Dr. Hubbard discussed nanotechnology applications to space exploration. For example, nanoteched devices and materials can be used to create lighter and smaller spacecraft, which reduces the amount of power and fuel needed to propel these craft. Also, spacecraft can be designed to be more "intelligent," so that they can collect and return more precise information and help answer the question as to whether or not there is life on other planets.

United States Congress
Representative Mike Honda, 15th District of California

As a co-sponsor of House Resolution 766, designated the Nanotechnology Research and Development Act of 2003, Representative Honda is initiating the increase in federal funding for research and development in nanotechnology, beyond currently proposed federal amounts. Representative Honda represents the 15th Congressional District of California, the district known as the heart of Silicon Valley and globally recognized as the breeding ground of technology and innovation. Elected to the U.S. House of Representatives in 2000, he serves on the House Committee on Science and the Transportation & Infrastructure Committee. As evidenced at the Bay Area Nanotechnology Forum, Representative Honda is recognized as taking a leading role in informing and bringing Democrats and Republicans together to increase their understanding of the role of technology and its potential societal returns. He was also honored as the "High-Tech Legislator of the Year" by the American Electronics Association for his advocacy of the high-tech economy. H.R. 766 only further exemplifies Representative Honda's political activism in garnering support for technology in society, and his commitment to supporting Silicon Valley as the epicenter of the next technology revolution.

University of California,Santa Cruz
Dr. M.R.C. Greenwood, Chancellor

Dr. Greenwood is chancellor of the University of California, Santa Cruz, a position she has held since 1996. As chief executive, Chancellor Greenwood oversees a research university with combined undergraduate and graduate enrollments of over 14,000 matriculated students and an annual total budget of approximately $370 million. Dr. Greenwood is a recognized leader in science education and policy development. She has held a number of prominent positions, including an appointment as Associate Director for Science at the Office of Science and Technology Policy (OSTP) in the Executive Office of the President of the United States.

Nanosys, Inc.
Dr. Stephen Empedocles, Co-founder and Director of Business Development

Dr. Empedocles is a co-founder and director of business development for Nanosys, based in Palo Alto. Nanosys is working to develop nano-enabled systems that incorporate novel and patent-protected nanostructures to enable the low-cost fabrication of revolutionary high-value, high-performance applications in a broad range of industries from life and physical sciences to information technology and communications to renewable energy and defense.

Agilent Laboratories – Life Science Technologies Laboratory
Dr. Carl Myerholtz, Manager Molecular Systems Department

Dr. Myerholtz is manager of the Molecular Systems Department in the Life Science Technologies Laboratory (LSTL) at Agilent. The research in LSTL covers a range of technologies in support of customer solutions in genomics, proteomics, molecular diagnostics, and ultimately pathways and systems biology. Key research programs include the development of high-performance detection platforms such as nanopore technology for very fast single-molecule biopolymer analysis, microfluidics, new molecular diagnostics for cancer and cardiovascular disease, informatics, and novel bioreagents and assay protocols. The life-science industry is undergoing rapid change because of scientific and technological revolutions that are occurring in biotechnology, informatics, and more recently, nanotechnology. These technologies will accelerate the discovery and development of the next generation of high-performance therapeutics and molecular-based diagnostics, thereby allowing us to understand the complex biological pathways that enable each of us to function normally. The research will also provide

the molecular basis for understanding and treating disease, thus dramatically improving patient outcomes and quality of life, while decreasing healthcare costs overall. Beyond the pharmaceutical and healthcare industries, these technologies will also contribute to fields as diverse as agriculture, forensics, and homeland security.

University of California, Berkeley – Mechanical Engineering
Dr. Arunava Majumdar, Professor and Vice Chair of Instruction

Dr. Majumdar is professor and vice chair of instruction at the University of California, Berkeley. He is not only involved in nanotechnology research, but also in the training of future nanotechnology scientists and engineers. His research interests range from photon and electron transport in low-dimensional semiconductor nanostructures to biomolecular nanomechanics and microarray chips for protein and nucleic acid analysis. Dr. Majumdar received the NSF Young Investigator Award in 1992, as well as the Melville Medal and Gustus Larson Memorial Award for outstanding achievements from the American Society of Mechanical Engineers (ASME).

California State Legislature – Joint Committee for Preparing California for the 21st Century
Heather Barbour, Principal Consultant

Heather Barbour joined the Bay Area Nanotechnology Forum as a representative of the Joint Committee for Preparing California for the 21st Century, where she serves as principal consultant. This joint committee was created pursuant to the Senate Concurrent Resolution 51, chartered in 1999. The goal of this committee is to engage Californians in a broad public dialogue regarding the most pressing and profound challenges of the new millennium. The committee convened in September 2000, and adopted "Race, Diversity and Inclusion" as its first topic of focus. In the 2003–2004 year, technology is the area of analysis, with a narrowed focus on nanotechnology, biotechnology, alternative energy, and e-government. In 2004, the completion of the topic year, the committee will produce findings and recommendations for state technology policy.

Northern California Nanotechnology Initiative
Chris E. Piercy, President and Chairman

Chris Piercy is president and chairman of the Northern California Nanotechnology Initiative

(NCnano). The Northern California Nanotechnology Initiative is a regional economic development program committed to building the world's leading nanotechnology cluster here in Northern California. Its major organizational goals are to bring $6 billion in nanotechnology investment and grant money into Northern California and to create 150,000 new jobs locally by 2007. The goal of NCnano is to provide the unifying fabric that integrates universities, research labs, businesses, venture capital, local and regional governments, and entrepreneurs.

Joint Venture: Silicon Valley Network
Marguerite Wilbur, Chief Operating Officer

Marguerite Wilbur is chief operating officer of the Joint Venture: Silicon Valley Network. Joint Venture is a regional nonpartisan voice and a civic catalyst for solutions to issues that impact the Silicon Valley community. Ms. Wilbur has also served as the president and chief executive officer and currently designs and leads Joint Venture's programs, initiatives, and networks. Of the variety of publications that Joint Venture produces each year, one of its most notable contributions is the "Index of Silicon Valley," a yearly publication that measures the progress of the Valley toward its regional goals. At the Bay Area Nanotechnology Forum, Marguerite Wilbur spoke of Joint Venture's support of and anticipation of nanotechnology's potential to revolutionize the area's economy.

Bay Area Science and Innovation Consortium
Dr. R. Sean Randolph, President

Dr. Randolph is president of the Bay Area Economic Forum and its subsidiary program, the Bay Area Science and Innovation Consortium (BASIC). BASIC is an action-oriented collaboration of the region's major research universities, national laboratories, independent research institutions, and research and development-driven businesses and organizations dedicated to developing innovative collaborative programs that take advantage of the unique capabilities at Bay Area R&D institutions to provide solutions for critical national and regional challenges; advocating for the Bay Area at the regional, state, and federal levels for economic, policy and business issues and opportunities impacting research and development; and demonstrating the critical linkage between the Bay Area's infrastructure and its economic vitality.

Silicon Valley Manufacturing Group
Justin Bradley, Director of Energy Programs

Justin Bradley is the director of energy programs for the Silicon Valley Manufacturing Group (SVMG). The SVMG is organized to involve principal officers and senior managers of member companies in a cooperative effort with local, regional, state, and federal government officials to address major public policy issues affecting the economic health and quality of life in Silicon Valley. Currently, SVMG addresses the following five core issues: affordable housing, comprehensive transportation, reliable energy, quality education, and a sustainable environment. The SVMG is particularly interested in nanotechnology for its application to products involved with energy consumption and conservation (for example, using nanotechnology to create more efficient and durable lighting for homes and industries).

Needs & Recommendations

Through attendance at the Nanotechnology Forum held at the NASA Ames Research Center in August 2003, follow-up interviews with several of the expert presenters, and comprehensive research and analysis of external sources, a variety of recommendations have been identified which, when implemented, should help to foster the development of nanotechnology in the greater San Francisco Bay Area. These recommendations, upon closer examination, separate easily into two broad categories: those issues that impact the industry and its stakeholders from sources outside the industry (external factors) and those that affect it from within (internal factors).

External Factors

To foster nanotechnology's expansion within Silicon Valley, several goals have been identified that rely on external factors. These objectives are fairly complex and focus on such outside influences as economy, infrastructure, and resources.

Establishing Optimal Business Environment

Some of the primary concerns surrounding nanotechnology's expansion within Northern California have to do with the general business climate and the State government's "friendliness" toward businesses. The challenge is to ensure that Silicon Valley remains an attractive location to new companies seeking to establish themselves, or to existing companies either spinning off new divisions or relocating entirely from other parts of the U.S.

Dr. Stephen Empedocles, director of business development for Nanosys in Palo Alto, believes that Northern California's infrastructure is second to none."Nanosys could not have started anywhere else," Empedocles stated at the Nanotechnology Forum and echoed in a phone interview. "The Bay Area has the people, the partners, the resources, the capital … everything." This sentiment is echoed by Ross DeVol of the Milken Institute in Santa Monica, who stated that "businesses don't locate in California, nor do they stay here, because it's cheap. They are drawn by the state's vast market, its skilled workforce, its transportation system, and its educational and research institutions."

While this may be the case, the region is walking a razor's edge of fiscal viability. If the cost of living, already exorbitant compared to other parts of the country, increases much more or if the educational, social, or physical infrastructure of the region deteriorates, then the benefits of existing resources, a well-educated workforce, and an appealing climate in which to live and work may no longer translate to positive long-term cost effectiveness. The balance could very well tip in favor of other regions of the U.S. that rate lower in key areas but provide a more reasonable cost of living for businesses and their employees and therefore prove to be a more appropriate location overall. In order for businesses to flourish in this area, the region's stakeholders must work to maintain, if not improve, our standard of living, while concurrently working to counter the region's high cost of living through tax rebates and fostering an environment more supportive of business operations.

Ensuring Quality of Life

Just as the quality of the business environment is important to Silicon Valley's ability to become the nanotechnology world leader, quality of life for current and future nanotechnology workers will impact whether or not Silicon Valley can compete successfully with other regions in this race. Silicon Valley has it all—talent, resources, facilities—compared to any other region in the United States. However, Silicon Valley also traditionally has a higher cost of living and challenging transportation issues compared to any other area. It is therefore a concern that although Silicon Valley has excellent academic institutions and government research laboratories well-equipped to train future nanotechnology workers, the region may lose these same workers to other areas that allow for a better standard of living.

In order to attract and retain skilled nanotechnology workers to Silicon Valley, several changes need to be made to the current quality-of-life infrastructure. First and foremost is creating affordable housing. As it stands, despite the economic downturn, it is still costly to rent or own housing in Silicon Valley—on average, $1,308 per month to rent an apartment and $509,000 to buy a home. Affordable housing therefore must be a priority, with cities willing to build affordable housing in their communities so that area workers can afford to live where they work. Also, transportation infrastructure must be improved and expanded to better serve the needs of workers. As seen during boom times, commuting in Silicon Valley has been a challenge—roadways were typically saturated with commuters, and bus and railway systems were limited in range. With the economic downturn, there have been fewer commuters on the roadways,

reducing the time spent traveling. Steps are also being taken to extend bus and rail services to cover more Silicon Valley communities. However, at the same time, the Valley Transportation Authority is facing a 21 percent service reduction. Hopefully, in the long run transportation improvement projects will win out so that workers will be able to easily and quickly commute to work in the future.

Silicon Valley must become a more affordable, less time-consuming place to live. Otherwise, time and money spent training nanotechnology workers will essentially be wasted, as talented and knowledgeable workers continue to move out of Silicon Valley for friendlier environs.

Increasing Support for Start-Ups

Increase Seed-Stage Funding

Currently, venture capitalists are hesitant to support the research and development efforts of start-up firms in nanotechnology. The reasons? First, as Meyya Meyyapan, director of the Nanotechnology Research Center at Ames states,"it takes 15 years to get from the lab to product" in fields of hard science. Second, venture capitalists are traditionally more interested in participating in late-stage funding investments, where product launch is close to inevitable. The development of nanotechnology, however, is unlike the technologies developed during the dot-com boom. Nanotechnology requires significant upfront capital for research, manufacturing, and development needs if research itself is even to have the opportunity to begin. As Steve Jurvetson of Draper Fisher and Jurvetson, one of the most aggressive investors in small tech firms, stated about nanotechnology, "It's not like this is the sort of technology you can tinker around with in your garage." While it is the case that the U.S. government is the nation's largest investor in nanotechnology, nanotechnology in Silicon Valley cannot maintain its preeminence in this field short of funding support from venture capitalists.

Other parts of the nation, particularly Albany and Austin, have received significant attention for their nanotech efforts as both have attracted levels of capital to create facilities and jump start nanotechnology in their areas with the intent of becoming the leaders in nanotechnology development. Silicon Valley also has the opportunity to attract additional capital, as federal funding offered by the Department of Defense's Small Business Innovation Research (SBIR) and Small Business Technology Transfer grants has been made available. Yet the funding levels made available are insufficient to meet the significant upfront capital costs. As Dr. Empedocles from

Nanosys added, the challenge in Silicon Valley is that this region's cost structure makes it challenging to start a company with an SBIR grant. The first phase of funding offered through this source is a maximum of $100,000, which when calculated in real terms, is less than one full-time employee. Thus, while federal funding exists, additional funding sources are necessary.

For Silicon Valley to remain ahead of the competition in nanotechnology, companies, both start-ups and established firms, and other researchers will need to continue to pursue federal funding. Moreover, for Silicon Valley's nanotechnology research and development efforts to actualize into products viable for market attention, existing seed-stage funding and development needs must be fulfilled. Recommendations from leaders in this field indicate that the region needs to proactively collaborate the efforts of companies, academia, and other groups as well as continue to pursue federal funding opportunities and venture capital investments.

According to Chris Piercy, president and chairman of NCnano, "We're lucky because here in Silicon Valley we are the world leader in a number of technologies. Nanotechnology is not really an industry, but more an enabling technology, and where we are going to find the most promising future of this field is through convergence technologies. The downside to this is that there is still a lack of regional coordination, relatively speaking. Albany and Texas and other areas are pulling in billions of dollars to create foundries, develop infrastructure, help start-up companies, etc. Here in the Bay Area, we're home to dozens of nanotechnology start-ups, but unlike those other states, most of these start-ups are on their own until they raise their first major funding round. This means that as a region, we are also not able to fully leverage the already existing high-tech infrastructure Silicon Valley has, for the purposes of nanotechnology company development."

Access to Nanotech Research Centers

Leaders of businesses, government, and other organizations took the opportunity at the Bay Area Nanotechnology Forum to communicate the need for a formalized cooperative effort to take place between university and federal research labs and researchers at start-ups. Given the facilities and equipment required for nanotechnology research, Silicon Valley is in need of establishing coordinated nanotechnology research centers, such as those found in New York and Texas. Nanotechnology research is expensive, and currently, in the absence of sufficient seed-stage funding for development projects, the progress of nanotechnology in the Bay Area would

profit from housing central nanotechnology facilities that start-ups could access for research and development purposes.

Educating Decisionmakers

As nanotechnology still qualifies under the categorization of an "emerging technology," the growth of this sector is predicated on external organizations' understanding of its value. Currently, as an emerging technology, there is a significant amount of clarification required on what the technology is, what it is not, and the potential for Silicon Valley to be the next technological and economic revolution for both Silicon Valley and the nation. As mentioned throughout this paper, the success of nanotechnology requires the combined efforts of all sectors, and particularly, funding from government resources. In order to ensure that nanotechnology has the funding it requires for research to continue, it is imperative that the federal and state governments are informed as to the latest discoveries in nanotechnology, both nationally and internationally. If nanotechnology in Silicon Valley and in the U.S. is to obtain a competitive edge, those individuals who can facilitate nanotechnology's progress need to be made knowledgeable on the topic, and moreover, remain informed. As a new generation of government leaders makes funding decisions for the future of emerging technologies such as nanotechnology, these leaders need to understand the investments and the collaborative infrastructure required for nanotechnology's progress alongside an understanding of the technology itself.

Proactively Working to Ensure Future Success

As mentioned earlier in this document, Silicon Valley has a rich 60-year history of technological success that has resulted in its establishment as the premier center of innovation and as an economic driver across the globe. According to a 2001 report produced by Global Insights, the San Francisco Bay Area (comprised of five metropolitan regions) ranks as the 28th most prosperous region in the world with an annual gross product of $338.84 billion—greater than 80 percent of U.S. states and all but 15 countries.

Despite this amazing claim, there is no guarantee that the successes of the past will continue into the future and there is significant concern that the region appears to be resting on its laurels, rather than proactively working to ensure that success is maintained."Many other areas are bringing in money and are calling attention to themselves," stated Dr. Empedocles of Nanosys.

"These regions may someday take the lead away from the Bay Area, as there is no concerted effort here."

While the Bay Area may be behind the curve in contrast to regions such as Boston, Austin, or Albany, it is this very cohesion that the recent Nanotechnology Forum at NASA Ames Research Center was striving to achieve. By bringing together key stakeholders in these emerging technologies, the region is just beginning to develop a single voice and common goals. It is essential that we continue to actively pursue these measures to ensure that the achievements that brought success in the past continue to foster growth into the future.

Internal Factors

Regional Goals: The Three "C"s

The goals that rely on factors internal to the industry and its stakeholders can be stated simply as the three "C"s: collaboration, communication, and commercialization.

1. ***Collaboration***

In order to become a world leader in nanotechnology, Silicon Valley must first learn to better collaborate. Researchers must work together with entrepreneurs, local politicians with educators, and so on, as nanotechnology needs the support of all industries and groups in order to succeed —nanotechnology is, after all, a high infrastructure-demand technology.

2. ***Communication***

With collaboration comes the need for clear and open lines of communication about the technology, its uses, and what is required to make nanotechnology succeed. Otherwise, for example, educators will not have a clear understanding of how to best train future nanotech workers, which will definitely impact the ability of nanotech employers to compete successfully in the marketplace. Also, a clear, strong, unified voice advocating for nanotechnology funding and support will always be needed, otherwise Silicon Valley will lose out – as it has already – to other locations that may not have nearly the infrastructure, but that have been able to clearly advocate for their own needs for nanotech funding.

3. ***Commercialization***

Once Silicon Valley is able to collaborate between groups and communicate findings and advocate for funding, it must be able to apply nanotechnology to real-world products in order to survive. After all, consumers don't buy science—they buy products. Since nanotechnology requires an enormous amount of funding in order to advance, being able to sell nanoteched products in the marketplace will help support and grow the infrastructure.

It is estimated that nanotechnology revenues may top $1 trillion worldwide in the next twelve years. If this is the case, and if Silicon Valley is able to position itself as the leader in nanotechnology, the large influx of money from this market may be used to help not only those industries directly involved with nanotechnology, but also other services and groups that make Silicon Valley a great place to live and work. It is easy to see how, with a concerted regional effort toward achieving these shared goals, Silicon Valley can move to the forefront of this amazing, enabling technology. It is also easy to see, however, how Silicon Valley could fail if even one of these elements is lacking.

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Authors

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About NOVA

NOVA (North Valley Job Training Consortium) is a non-profit, federally funded employment and training agency dedicated to providing innovative, high-quality, customer-focused workforce development services. To accomplish this goal, NOVA works closely with local businesses, educators and job seekers to ensure that our programs provide opportunities that build the knowledge, skills and attitudes necessary to address the workforce needs of Silicon Valley. NOVA is a seven-city consortium consisting of the cities of Cupertino, Los Altos, Palo Alto, Milpitas, Mountain View, Santa Clara, and Sunnyvale, under the direction of the NOVA Workforce Board. For more information about NOVA, please visit www.novaworks.org.

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