



Blue Ribbon Task Force on

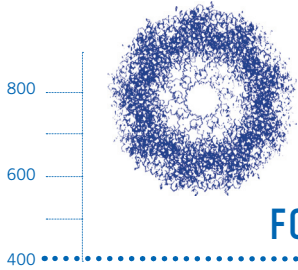
NANOTECHNOLOGY

**THINKING BIG ABOUT THINKING SMALL**

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An Action Agenda for California





## FOREWORD

In recent years, nanotechnology has emerged as a promising new industry with a broad range of valuable applications. Reports at the national and international level have been published to varying degrees of public attention, but the publication of this white paper represents a significant step in assessing the state of nanotechnology in California and developing policy solutions for making the industry a statewide success.

Over the past year, members of the Blue Ribbon Task Force on Nanotechnology (BRTFN) have worked diligently to address the major areas of concern in promoting nanotechnology research and development, commercialization, facilities and infrastructure, policies and ethics, and education. The members of the Task Force come from many backgrounds including academia, government, corporate California, start-up firms and consulting firms, non-profit groups and industry associations. Their wide range of expertise and experiences has added great value, depth and perspective to this paper.

It is particularly fitting that the membership of the BRTFN features rich diversity of regional representation, background, expertise, ethnicity and gender. California's premier innovators come from a variety of backgrounds and are based through the state, a testament to the strength of California's diverse population and the potential for the success of nanotechnology as a statewide industry.

We would like to thank the members of the Task Force for committing their time, energy and expertise to developing this white paper and the recommendations within. We also extend our thanks and appreciation to Dr. G. Scott Hubbard for his expert leadership as working chair of the BRTFN. Finally, we would like to recognize BRTFN affiliates, special advisors and staff members, both at our respective offices as well as at NASA Ames Research Center, for their support and assistance in this project.

Promoting nanotechnology in California is a task that requires foresight, innovation, a significant investment of expertise and resources, and pro-active government policy solutions. The Blue Ribbon Task Force on Nanotechnology has identified and examined many of the core issues surrounding nanotechnology and offered recommendations for leveraging statewide strengths and addressing scientific and public concerns.

We will carefully consider these recommendations as we pursue innovative state and federal strategies to ensure that nanotechnology thrives in California.

Sincerely,



*Michael M. Honda*

Michael M. Honda  
Member of Congress



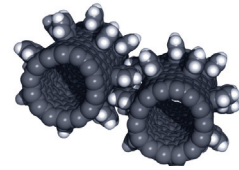
*Steve Westly*

Steve Westly  
California State Controller

# FINDINGS AND RECOMMENDATIONS FOR THE STATE OF CALIFORNIA

## CONTENTS

i. Executive Summary .....	4
ii. Introduction .....	6
iii. The Importance of Nanotechnology to California .....	7
iv. The Creation and Mission of California's BRTFN .....	7
v. California's Current Nanotechnology Infrastructure.....	8
vi. BRTFN Findings and Recommendations .....	10
Recommendation 1: .....	10
Building on California's Existing Strengths	
Recommendation 2: .....	14
Bridging the Innovation/Commercialization Gap	
Recommendation 3: .....	17
Promoting, Marketing and Coordinating at the State Level	
Recommendation 4: .....	18
Launching a 'California Innovation Initiative'	
Recommendation 5: .....	20
Preparing a Globally Competitive Workforce	
Recommendation 6: .....	22
Understanding and Communicating the Ethical, Environmental, and Societal Implications of Nanotechnology	
Recommendation 7: .....	24
Addressing Business Climate Concerns in California	
Recommendation 8: .....	25
Empowering Organizations to Continue the BRTFN Mission	
vii. Final Thoughts .....	27
viii. Acronyms .....	28
ix. References .....	29
x. Task Force Members .....	34
xi. Other Contributors and Special Thanks .....	35



## EXECUTIVE SUMMARY

While nanotechnology – the manipulation and exploitation of the unique properties of matter at the atomic scale – is a relative newcomer to our arsenal of technical capabilities, it would be hard to overstate its potential or importance. It holds the promise of revolutionary breakthroughs in medicine, energy, environmental controls and many other fields, with the anticipation of new research, products, jobs and entire industries.

For that reason, the United States developed and implemented a national nanotechnology policy more than five years ago. To preserve its technology leadership and economic strength, the state of California must now embrace the nanotechnology challenge.

To that end, State Controller Steve Westly and Congressman Mike Honda appointed a Blue Ribbon Task Force on Nanotechnology (BRTFN) in December 2004. Under the working chairmanship of NASA Ames director Scott Hubbard, the BRTFN's mission is to evaluate the status of nanotechnology in California and recommend what actions are needed on the part of State and Federal policy makers to ensure California's leadership in the field. This final report summarizes the Task Force's findings and recommendations to Controller Westly and Congressman Honda.

Overall, we find that California has an excellent infrastructure, encompassing world-class universities, national labs and the private industrial base. Our state is well positioned to compete, and lead, in the nanotechnology age. The BRTFN finds, however, that policy makers must take urgent action in eight key areas if California is to remain competitive and achieve its potential in nanotechnology research and product commercialization.

(1) We must **Build on California's Existing Strengths** in semiconductors and biotechnology to assert state leadership in nanoelectronics and nanobiotechnology. The BRTFN urges strong and proactive state action designed to:

- Develop a state response to the tax incentives and grants of foreign governments and the subsidies to manufacturers provided by other U.S. states;
- Provide increased state funding for California universities to compete for nationwide consortia research grants; and
- Provide essential funding for the semiconductor Focus Center Research Program.

California must also take advantage of its strong existing nanotechnology infrastructure and implement a comprehensive strategy for improved access and resource sharing to enhance product commercialization. This is particularly important for nanotechnology start-ups seeking to avoid costly investments in infrastructure with no real value added.

Further, we must foster the development and marketing of California's nanotechnology business clusters. This can be accomplished by creating special 'start-up zones' adjacent to research universities and national labs; implementing a state income tax holiday for companies making investments in capital and hiring or training workers associated with new nanotechnology product lines; restoring the exemption from sales tax for the purchase of capital equipment; and making effective use of application-specific development funds to support collaborative nanotechnology research in such fields as alternative energy sources, the environment, security and health.

(2) California must make it a priority to **Bridge the Innovation/Commercialization Gap**. To that end, the BRTFN proposes that the state provide applied research matching funds to innovation centers in conjunction with private investment; launch a state-based Small Business Innovation Research (SBIR) program; and influence state universities and California-based national labs to simplify and clarify their licensing and intellectual property processes to enable the accelerated transition of ideas from the lab to the marketplace.

(3) California must institute a strategic approach to **Promote and Market** its nanotechnology assets and **Coordinate** efforts to pursue federal funding at the state level. Specifically, California must actively promote itself





as a world nanotechnology leader by hosting and sponsoring events such as ‘Nano Weeks’ and a California ‘Nano Portal.’

The BRTFN recommends that the state empower an entity with membership from across the spectrum of major California businesses, federal and state agencies, and academic institutions to lead strategic and proactive promotion, marketing and coordination efforts.

(4) The BRTFN proposes that the state **Launch a ‘California Innovation Initiative’** to take advantage of the powerful convergence of the very strong base of bio, info, and nanotechnology assets in California. Elements of such an initiative might include:

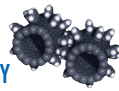
- Providing funds to operate the California Institutes for Science and Innovation;
- Exploring ways to increase angel and early-stage investment in startups that are commercializing converging technologies;
- Encouraging state agencies to identify areas where California can be an ‘early customer’ of new technologies;
- Taking steps to expand California’s bio, info and nano workforces; and
- Providing mid-career professionals with re-education assistance programs.

(5) The State of California must take steps to ensure that its education system, at all levels, is adequate to **Prepare a Globally Competitive Workforce** that is essential to compete effectively in high-tech business. To that end, California should:

- Require at least one hour each of quality math and science instruction daily for all of the state’s K-12 students, and prioritize the needed extensive recruitment and training of new teachers and professional development of existing teachers, particularly in schools in low and middle income areas;
- Provide new funds in the public university and community college system budgets to enable the creation of interdisciplinary courses in nanotechnology;
- Encourage high-tech companies to assist in the creation of training courses that support nanotechnology manufacturing;
- Encourage national labs with nanotechnology expertise to provide content suitable for developing nanotechnology exhibits;
- Require informal education centers that have developed nanotechnology materials to share their efforts with others; and
- Sponsor efforts to develop and coordinate statewide collaboration of science museums and informal education venues.

(6) California should lead pioneering efforts to **Understand and Communicate the Ethical, Environmental and Societal Implications of Nanotechnology**. Among other things, the California Environmental Protection Agency (Cal/EPA) and the California Department of Health Services should:

- Track health data about nanotechnology so that appropriate and timely actions can be taken before problems develop;
- Promote environmentally beneficial applications of nanotechnology through an active program of research, pilot projects and field trials;
- Negotiate an information-exchange and problem-solving agreement with nanotechnology manufacturers concerning responsible stewardship of nanotechnology products; and
- Lead in the implementation of responsible environmental applications of nanotechnology.



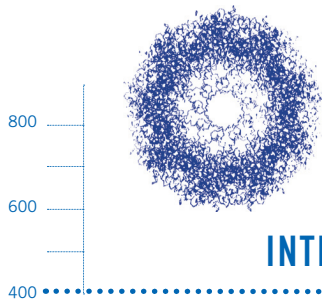
In addition, the state should leverage its strength in entertainment and science museums to increase public awareness and understanding of nanotechnology; encourage widespread and rapid adoption of alternative energy sources through tax and regulatory policy; and establish credible, independent sources of information about nanotechnology.

(7) While there are no easy fixes, it is essential that policy makers take steps to **Address Business Climate Concerns in California** so as to level the playing field for state-based businesses relative to those in other states and countries. This might include consideration of income tax holidays and sales tax exemptions, among other actions. California should also work with the federal government to alleviate the burden of excessive, costly and confusing business regulations. Finally, State policy makers should enlist California’s Federal legislative delegation to explore avenues to amend current SBIR regulations to permit venture capital-backed startups to qualify for SBIR awards.

(8) The State of California should **Empower an Organization or Organizations to Continue the BRTFN Mission**. This might be accomplished through a centralized unit and function, or through one or more regional consortia charged with building partnerships and collaborations encompassing the breadth and diversity of California institutions involved in nanotechnology research and commercialization. Whichever path is chosen, the designation and empowerment of a responsible group is a critical first step.

Overall, California is well positioned for international leadership in nanotechnology. However, a strategic and coordinated state-led effort is essential to achieve success. We must act quickly in implementing an action-oriented and aggressive agenda to ensure California’s continuing role as a leading world economy.

We are already in the midst of a nanotechnology revolution of unprecedented magnitude and economic impact. It is absolutely vital that California step up to this leadership challenge. This report is both an urgent call to action and a blueprint of recommendations for how best to proceed.



The term ‘nanotechnology’ refers to the conduct of engineering and applied science at an ultra-small scale – in a size range on the order of 100,000 times smaller than the diameter of a human hair.<sup>1</sup> This focus on miniaturization can result in tremendous cost savings and is one extremely important aspect of nanotechnology. However, equally important is the fact that many materials exhibit very different physical, chemical, biological, mechanical and electrical properties at the nanoscale than they do at the macroscale. Nanotechnology allows us to exploit those novel properties to create functional materials, devices and systems with unique capabilities. The range of applications, and therefore the magnitude of potential benefits, is virtually unlimited.

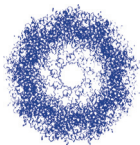
Recognizing this, the United States launched a National Nanotechnology Initiative (NNI) in February 2000 that envisioned “a future in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry.”<sup>2</sup> A subsequent White House news release announcing the 21<sup>st</sup> Century Nanotechnology Research and Development Act in December 2003 was even bolder, asserting that, “nanotechnology offers the promise of breakthroughs that will revolutionize the way we detect and treat disease, monitor and protect the environment, produce and store energy, and build complex structures.” It predicted that nanotechnology would have “a broad and fundamental impact on many sectors of the economy, leading to new products, new businesses, new jobs, and even new industries.”<sup>3</sup>

## THE IMPORTANCE OF NANOTECHNOLOGY TO CALIFORNIA

California already has a dominant economy, the fifth largest in the world in terms of gross domestic product.<sup>4</sup> The State boasts a leadership position in many large and growing markets, most notably, semiconductors and biotechnology. Nanotechnology plays a critical role as an ‘innovator’ for these markets, enabling both the next generation of semiconductor devices with nanoscale feature sizes and the engineering of new drugs at the molecular level. Nanotechnology also provides an edge in winning a larger share in emerging markets, such as clean energy. Moreover, through the characterization, design and fabrication of new materials, the manipulation and control of matter at the nanoscale serves as a major driver of next-generation, so-called ‘disruptive’ technologies. These technologies are critically important to the California economy because they will impact an ever-increasing set of markets, from defense and security to biology and medicine.

More than 1,000 companies are currently working in the nanoscale environment,<sup>5</sup> crossing the boundaries of chemistry, physics and biology to take advantage of unique nanoscale effects that will drive commercial development. This will lead to breakthroughs in old-line industries as well as completely new technologies, with some predicting a \$1 trillion market by the year 2017.<sup>6</sup> In terms of population effects, the numbers are equally striking – the possibilities offered by nanotechnology are projected to impact over 350,000 chemical, materials and petroleum engineers and 180,000 life sciences engineers in the U.S. alone.<sup>7</sup>

Clearly, to retain its leadership position and to protect the health of its economy, California must be a major player in the nanotechnology revolution that is upon us.



## THE CREATION AND MISSION OF CALIFORNIA'S BRTFN

Cognizant of the foregoing, and seeking to capitalize on California’s entrepreneurial spirit, unique infrastructure and expansive resource base, Congressman Mike Honda (CA-15) and State Controller Steve Westly chartered the Blue Ribbon Task Force on Nanotechnology on Dec. 17, 2004. The BRTFN is a 48-member panel comprising nanotechnology experts from industry, academia, government and venture capital from across the State.<sup>8</sup> Its mission is to offer recommendations to Controller Westly and Congressman Honda regarding the promotion of California as the national and worldwide leader in research, development and commercialization of nanotechnology.

Under the leadership of its working chair NASA Ames director Scott Hubbard, the BRTFN formed five subcommittees with two specific goals: The first charge was to assess the present state of nanotechnology in California with respect to infrastructure and assets, research and development, commercialization, policy and ethics, and education. The second mandate was to determine what actions are required on the part of California policy makers at the federal and state levels to maintain and enhance California’s leadership position in nanotechnology.

This document assesses the State of California’s current nanotechnology infrastructure and summarizes the BRTFN’s findings and recommendations for ensuring California’s place as a national and international nanotechnology leader.



## CALIFORNIA'S CURRENT NANOTECHNOLOGY INFRASTRUCTURE

California is in an enviable position, well poised to compete in the nanotechnology age. The State's strong historic track record of technological leadership is one major reason. Emergence of the Silicon Valley, Los Angeles and San Diego high-tech regions as fertile grounds for innovation and entrepreneurship, including nanotechnology, is another.

In the competition for leadership and markets, however, perhaps the most important factor is a state's nanotechnology infrastructure, the foundation upon which existing companies can draw and new companies can build. California is well positioned in this regard, too, possessing nearly all of the infrastructure elements required for success, most notably, its world-class universities, national laboratories and private industrial base.

In terms of universities and academic research institutions, it can be argued that California has no peers, either nationally or internationally. No other state has a combination of public and private universities with such a strong record of nanoscience research and other significant infrastructure to rival California.

The University of California system, for instance, houses four California Institutes for Science and Innovation: the California Institute for Quantitative Biomedical Research (QB3), the California Nanosystems Institute (CNSI); the California Institute for Telecommunications and Information Technology (CallT2), and the Center for Information Technology Research in the Interest of Society (CITRIS).<sup>9</sup> CNSI alone has invested approximately \$100 million into research infrastructure at the Universities of California at Los Angeles (UCLA) and Santa Barbara (UCSB). UCSB is also the lead in the Institute for Collaborative Biosciences, a \$50 million consortium with the California Institute of Technology (Cal Tech) and the Massachusetts Institute of Technology (MIT) focused on merging advances in nanomaterials and biotechnology. In addition to serving as home to many pioneers of the nanoscience revolution, University of California at Berkeley (UCB) houses the National Science Foundation (NSF)<sup>10</sup> Center of Integrated Nanomechanical Systems.<sup>11</sup> The NSF Center for Biophotonics, Science and Technology,<sup>12</sup> based at the University of California at Davis (UCD), takes advantage of its partnership with the UCD Cancer Center<sup>13</sup> to bring nanophotonic tools to bear on cancer research and treatment. It also conducts research and graduate education in the area of Nanoparticles in the Environment, Atmosphere and Technology. Similarly, both the University of California at San Diego (UCSD) and Santa Cruz (UCSC) have significant research programs in nanoscience.

Beyond the UC system, California's university community arguably features more resources, capability and visibility in nanoscience than most other states or nations. Both Cal Tech and Stanford are among the top research institutions in the country in this field. In terms of infrastructure, the Stanford Nanofabrication Facility<sup>14</sup> has a strong foundation that is comparable to facilities at Cornell University,<sup>15</sup> and a 20-year track record of performance. When considered together, the resources of California's public and private university systems place it first in the nation and the world as a region of nanoscience infrastructure and research.

The second component of California's nanoscience infrastructure consists of its national laboratories, federal research facilities, in particular, NASA Ames Research Center, Lawrence Berkeley National Lab (LBNL) and Lawrence Livermore National Laboratory (LLNL), as well as the Livermore campus of Sandia National Laboratory (SNL).

The NASA Ames Center for Nanotechnology explores novel concepts in electronics, computing, sensors and advanced miniaturization. The Center develops and validates future-generation electronic devices, materials and processes, as well as ultra-small sensors and detectors 1,000 times more sensitive than current technology. NASA Ames is also home to the 10,240-processor 'Columbia' supercomputer, one of the world's fastest computer systems.<sup>16</sup>

The University of California has partnered with NASA in the University Affiliated Research Center,<sup>17</sup> a \$330 million collaboration with an emphasis on bio- and nano- research. The UC system is also planning to construct a new Bio-Info-Nano Research and Development Institute (BIN-RDI)<sup>18</sup> in the Ames-based NASA Research Park,<sup>19</sup> a \$65 million facility that promises to become a leader in nano-convergent science and technology.





LBL is home to the Molecular Foundry,<sup>20</sup> one of five Department of Energy (DoE) Nanoscale Science Research Centers.<sup>21</sup> The Foundry features research laboratories and state-of-the-art equipment for materials science, physics, chemistry, biology and molecular biology. Like other DoE user facilities, including the Advanced Light Source at LBNL<sup>22</sup> and the Synchrotron Research Center<sup>23</sup> near the Stanford campus, the Foundry serves as a national resource for researchers seeking to capitalize on the expertise in synthesis, characterization, and simulation of nanomaterials developed at LBNL over the past decade.

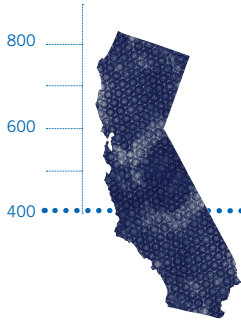
In the past five years, LLNL has established the Biosecurity and Nanosciences Lab<sup>24</sup> and the Nanoscale Synthesis and Characterization Laboratory,<sup>25</sup> which focus on applications of nanoscience to technical challenges of national security. LLNL has invested in development of a Quantum Simulations Group,<sup>26</sup> which takes advantage of LLNL's terascale computing facilities to develop first-principles codes for simulation of the growth and performance of nanostructures such as quantum dots and nanotubes. Furthermore, Sandia has a long-standing, world-renowned capability in scanned-probe and low-energy electron imaging of the growth of thin films and nanostructures at surfaces.

Like the State's university systems, these national laboratories give California a formidable resource and a competitive advantage in nanoscience and technology.

The third major component of California's nanotechnology infrastructure is the State's industrial base. Nanotechnology can be explained as the convergence of three domains: materials science, biotechnology and semiconductors. California is a leader in two of these domains: biotech and semiconductors. This leadership, in turn, has contributed to California's current nanotechnology strength. A full 15% of all nanotechnology companies worldwide reside in California, including industry development leaders such as Hewlett-Packard, Intel and Agilent. In the U.S., California is the national leader, with 27% of all nanotech companies nationwide located in our state. Further, in the top three categories of nanotech companies – nano-bio, nano-devices, and nano-instruments, 30%, 37%, and 25%, respectively, of these companies are located in California, further ample evidence of California's current leadership position in nanotechnology.<sup>27</sup>

From an organization perspective, start-up companies that have "spun out" of academic research groups are a strong driving force for innovation and growth in nanotechnology, especially here in California. Nevertheless, the bulk of California's industrial capability lies with existing high-tech companies, particular those in Silicon Valley. In fact, most of the region's large chip manufacturing and microelectronics firms have been using in-house nanoscience infrastructure for years to take advantage of nanoscale engineering and the unique physical properties of materials at the nanoscale. Clearly, the State's high-tech industrial sector already has much of the infrastructure needed for California to lead the world in nanotechnology, much as it was a leader in the field of microelectronics.

Overall, California is consistently rated as one of the principal sites in the U.S. and the world to lead in nanotechnology. Our State consistently ranks highly in multi-criteria, nanotech-oriented state comparison studies. In an evaluation based on the six categories of research, industry, venture capital, innovation, workforce and costs, Small Times Media ranked California as first in March 2005.<sup>28</sup> A similar study by Lux Research ranked California as second among U.S. states, behind only Massachusetts. The emergence of Silicon Valley namesakes in more than 100 high-tech regions of the U.S. also attests to the visibility of California's success in high-tech and, specifically, nanotechnology.



## BRTFN FINDINGS AND RECOMMENDATIONS

California clearly has a major advantage when it comes to leadership in nanotechnology. One key factor is the State's strong nanotechnology infrastructure delineated above. By virtue of our high-tech past, an abundance of major universities and national labs, and a strong industrial base, California already possesses many of the elements required for success. The State is well positioned to be a nanotechnology leader and exploit the economic and social benefits of this new industry. Similarly, the nanotechnology industry has many strong reasons to locate in California and take advantage of the infrastructure, entrepreneurial spirit and other resources that our State has to offer.

**However, success is not guaranteed. California faces numerous regional and international challengers. The competition is intense – from Boston to Bangalore. Proactive leadership and policies, at the State and Federal levels, are absolutely essential if California is to enjoy the benefits of a leading role in nanotechnology.**

Specifically, the BRTFN finds that California must build upon its strengths, through on-going and reliable support for nanotechnology research, especially interdisciplinary research that connects nanotechnology to the energy, medical, environmental, security, space and defense industries. The State must foster the development of special service industries that are important to the nanotechnology industry. California would be well served by a coordinated approach to nanotechnology investments and the promotion and marketing of the State's assets and infrastructure. California must seek ways to bridge the gap between innovation and commercialization to reap the benefits of the nanotechnology revolution. The State must take a hard look at its education system to ensure that it prepares workers at all levels for employment in high-tech industries. The State of California must address resident concerns about the uses of nanotechnology and seek opportunities to become an early customer for beneficial applications. Finally, State leaders must do everything possible to ensure a favorable business climate in California, including promoting safe, scientifically sound and appropriate environmental policies.

The BRTFN has consolidated its findings and suggested actions as part of eight recommendations. We elaborate on those recommendations in the following sections.



## RECOMMENDATION 1: BUILDING ON CALIFORNIA'S EXISTING STRENGTHS

California was the birthplace of the semiconductor and biotechnology industries and should remain strong in those fields especially as the State develops its budding nanotechnology industry. One might even expect California's headstart to lead to a dominant position in nanoelectronics and nanobiotechnology. However, while California and Silicon Valley have long been leaders in microelectronics, there is no guarantee that we will maintain that position as novel nanotechnologies transform the industry and other states and countries seek market share in the semiconductor industry. California faces significant challenges in the nanoelectronics field.

During the past four decades, the semiconductor industry has been able to double the number of transistors on a chip every eighteen months – a trend known as 'Moore's Law.'<sup>29</sup> Sustaining Moore's law and similar trends is not only key to the continued health of California's semiconductor industry, but also essential to the success of the many industries that depend on faster processing speeds and greater memory capabilities, such as computer, communications, software, Internet, e-commerce and digital entertainment sectors. Technologists today face two challenges – to keep pace with Moore's Law by squeezing every possible performance capability out of the current Complementary Metal Oxide Semiconductor (CMOS) microelectronics technology through new materials and device structures, and to find a replacement technology for CMOS before its limits are exhausted. Advances in nanoelectronics are vital for further technological progress and economic health, in the semiconductor industry as well as in the many industries that use semiconductors.<sup>30</sup>



California starts out with an enviable position in nanoelectronics, with leading companies and universities in the field. One example, the Focus Center Research Program<sup>31</sup> (FCRP), a partnership between the Department of Defense and industry to support university research in semiconductors, has a strong California presence with two of its five centers led by California universities, UCB and UCLA. However, other states and countries are making major investments to build and improve their manufacturing and research capability in semiconductors and nanoelectronics. California must respond with a solid strategy if we are to maintain our leadership as the semiconductor industry is transformed by the transition to nanoelectronics. On the domestic front, for instance, the Albany region received \$1.9 billion in pledges from private companies and \$150 million in New York State funds to build a new semiconductor fabrication plant and conduct nanotechnology research in 2005.<sup>32</sup> Internationally, substantial cost differentials, created largely by foreign government tax and subsidy policies, provide a strong pull to build factories outside of the U.S. The result is that, while 34 percent of the world's leading-edge semiconductor fabrication capacity was in the U.S. in the year 2000, that figure had fallen to 22 percent by 2004. Further, while 20 percent of 300 mm (leading edge) silicon wafer fabrication facilities under construction, equipping, or in production are in the U.S., a full two-thirds of such facilities are now located in Asia.<sup>33</sup>

House Appropriations chair Rep. Jerry Lewis and Senate Defense Appropriations Subcommittee Member Senator Dianne Feinstein have been very supportive of the FCRP in the past. Representatives Anna Eshoo and Darrell Issa have led delegation letters, and Governor Arnold Schwarzenegger has written to the President about the program. However, funding in the Department of Defense's budget has remained far short of that required to match the industry contribution, as called for most recently in the Defense Science Board report on microelectronics.

**Action: The California Congressional delegation should work to secure full funding for the semiconductor Focus Center Research Program. They should also urge the Administration to provide full funding for the FCRP in the President's budget.**

In semiconductors, there is a \$1 billion cost difference over ten years between building and operating a plant in the U.S. and overseas – 90 percent of which is due to tax incentives and grants (and only 10 percent due to labor and operating costs).<sup>34</sup> With the expiration of California's Manufacturers Investment Credit,<sup>35</sup> the State needs to develop an alternative response. The Governor should also use the National Governors Association to urge the federal government to work with state economic development agencies to ensure that the U.S. has a coordinated response to our competitive challenges. Under current law, if a state matches the tax benefit of a foreign government, it would find its effort diluted by the increased federal tax on the new investment.

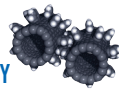
**Action: California policy makers should develop a state response to the tax incentives and grants of foreign governments and other U.S. states that subsidize plants competing (at some considerable advantage) with California manufacturing.**

The semiconductor industry has launched a Nanoelectronics Research Initiative (NRI) to find a replacement for CMOS.<sup>36</sup> The NRI builds on the existing government National Nanotechnology Initiative, such as the current NSF Nanoscale Science and Engineering Centers. The NRI research occurs at universities and will include industry assignees, with a first phase focused on generating as many new ideas as possible followed by a second 'proof-of-concept' phase. As the program proceeds, it is anticipated that other states will include matching state funds in their proposals to NRI, as they have in the semiconductor Focus Center program, to capture a leading research role for their state at this critical juncture and catalyze the growth of a new industry. To compete effectively, California must be prepared to include state-matching funds for its universities' proposals as well.

**Action: The California Governor and State Legislature should provide increased State funding for universities to compete for nationwide consortia research grants.**

In addition to ensuring California's leadership in nanoelectronics, another way to build upon California's existing strengths is to take advantage of the extensive nanotechnology infrastructure already resident in the State by addressing impediments to its efficient use. One obstacle is that university facilities are almost exclusively focused on academic research and education, while the facilities of the State's national labs are primarily dedicated to national security research and spaceflight. Rarely are these facilities readily available to companies in need of longer-term R&D, much less rapid turnaround services.

A second problem limiting effective use of California's nanoscience infrastructure is that, while the industrial base resides primarily in existing microelectronics and biotechnology firms, a great deal of the scientific know-how and intellectual property in nanotechnology is found in small start-ups that lack the extensive infrastructure of



well-established firms. In the absence of an effective way to share facilities and equipment, start-ups and publicly traded companies are forced to make investments (in duplicated resources) that do not add real value to their base. The result is that much of the value of California's existing nanotechnology infrastructure goes unrealized. Metrology and design tools are just two areas in which cooperation and shared access could lead to beneficial synergies.

**Action: California should develop a comprehensive strategy to enhance access to existing infrastructure and promote resource sharing in order to aid State business enterprises, particularly start-ups, in emerging areas like nanotechnology.**

Since companies developing new technologies typically require rapid turnaround of prototypes and experiments, the use of existing facilities may still not be viable.

**Action: The State of California should develop financial incentives to encourage capital investment in nanotechnology equipment by companies that provide quick-turnaround fabrication and testing of nanodevices.**

Even when it is possible to gain access to existing infrastructure in a timely fashion, legal impediments concerning intellectual property often constitute a significant entry barrier. Most universities and national labs currently operate under rules and procedures not consistent with the confidentiality of corporate user activities conducted in their facilities.

**Action: State and Federal policy makers should seek establishment of a blanket non-disclosure agreement that preserves confidentiality and is portable across university and lab systems. Also, the terms and conditions of equipment use and ownership of jointly developed intellectual property should be simple and unified across systems.**

More generally, developing a sustainable plan for funding nanotechnology infrastructure would help ensure California's long-term nanotechnology leadership and the resulting economic benefits. This is particularly important for existing, older facilities that usually cost less to refurbish than constructing and equipping new ones. A prime example is the Stanford Nanofabrication Facility that, after 20 years of stable operation, could be made far more valuable to the local nanotech community with appropriate equipment upgrades.

**Action: Additional State and Federal funding should target the operational needs of existing nanoscience centers, including equipment and facility upgrades.**

The inherent need for measurement and manipulation at the atomic level also calls for software tools that enable companies to predict novel properties, rationalize existing measurements and design innovative devices. Software tools that have been developed in California's universities and national labs, even if physically available, are complex and difficult to utilize. Software that can provide nanoscience engineers with a bridge between the macro- and nano-device design worlds should be developed through a highly cross-disciplinary collaboration among researchers with a broad expertise base.

**Action: The State should seek establishment of an NSF Nanoscale Science and Engineering Center for 'nano-CAD' tools. Strong private partners could ensure R&D aligned with systems-level needs and state-of-the-art industrial challenges.**

One final way to build upon California's existing strengths is to support those elements that make the State 'special.' In California's case, one key feature is that, over time, the State's high-tech regions and industries have become fertile habitats for innovation and entrepreneurship. Many other regions in the world feature innovation with minimal entrepreneurship, or entrepreneurship with minimal technology innovation. When the two factors co-exist, as in Silicon Valley, they comprise a very powerful engine for creating new product lines, new companies, and whole new industries. This phenomena is known as 'clustering,' and the grouping of high-tech firms engaged in the commercialization of related technologies in a given geographic region is a 'cluster.' Clustering is the tendency for mutually supportive organizations to co-locate in order to promote a productive ecology for growing companies.<sup>37</sup>

It is difficult to overstate the importance of clustering to California and its high-tech regions. Clusters of emerging start-ups and growing companies not only commercialize important technologies of benefit to society, but also



have significant impact on regional and state economies. Further, they give rise to the growth of a surrounding environment of service and support industries, creating another business layer and further multiplying their economic impact. In addition, once a cluster is started, many additional spin-offs typically emerge, spawning yet another set of emerging new companies and start-ups, usually located close to the original home base.

Clustering is also important from the perspective of international competition. It has helped make Silicon Valley a region that develops technologies into businesses by fostering a dynamic interaction among research, product innovation and markets. The supporting habitat permits these developments to unfold rapidly, keeping California on the leading edge of new industries with respect to both research and product commercialization. While it is important for California companies to reap the benefits of continued innovations that incrementally improve current product lines, from the viewpoint of international competition it is especially important for California companies to rapidly develop the disruptive technologies that alter the terms of competition in California's favor. Both the potential benefits and the economic stakes are immense.

**Action: California's local, regional and state policy makers should facilitate the emergence, development, promotion and marketing of California's existing and developing nanotechnology business clusters. Since early-stage business activities stay close to their origins, California should promote start-up activity by identifying the location of existing and developing nanotechnology clusters and emphasizing to other potential commercial entrants the advantages of locating within these clusters.**

One direct way to build clusters, while also facilitating small-businesses access to existing high-value infrastructure, is through the creation of special 'start-up zones' adjacent to California's research institutions. An excellent example that can serve as a model for this type of development is NASA Research Park (NRP) located at Ames Research Center. The NRP is rapidly becoming a world-class, shared-use R&D and education campus focused on astrobiology and bio-info-nano convergence that leverages taxpayer dollars. California's three public higher education institutions –University of California, California State University and the Community College systems – have partnered with NASA in the NRP alongside more than 30 private companies, many start-ups and small businesses. Proximity and access fuel both innovation and commercialization.

**Action: The State of California should create special 'start-up zones' adjacent to research universities and national labs to encourage clustering, enhance resource sharing and infrastructure access, and promote collaborative research.**

Cities can also leverage the State's advantage in nanotechnology development by attracting, supporting and retaining companies that develop nanotechnology. The City of San Jose's Redevelopment Agency, for instance, invested \$6.5 million to design and construct the San Jose BioCenter, a 36,500 square-foot, state-of-the-art laboratory for start-up entrepreneurs and scientists. The incubator offers world-class wet labs, dry labs, office space, common equipment rooms and other shared facilities. In operation since July 2004, it is now home to 15 start-up companies, two focusing on nanotechnology.

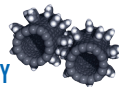
Investments by cities in large-scale projects like the BioCenter are critical to the advancement of nanotechnology clusters in California. However, not all cities can generate sufficient revenue to initiate a nanotechnology incubator. Other strategies for cities to support nanotechnology include economic development efforts to match the needs of emerging nanotechnology firms with existing local infrastructure and available resources. Furthermore, cities can initiate loan programs to start-up companies for expansion, inventory, working capital and other business expenses.

**Action: California's cities should take appropriate steps to support nanotechnology clusters within their region.**

Another way to build strong nanotechnology clusters in California's high-tech regions is through the use of tax incentives to attract businesses to the State in key areas, such as nanoelectronics, nano-instruments, nano-bio, nano-energy and nanomaterials.

**Action: California should implement a State income tax holiday for corporations and/or start-ups structured such that companies that make investments in capital and hiring/training workers associated with new nanotechnology product lines receive 10 years of California State income tax exemption for that product line. Investments made during the next 5 years would qualify for the tax holiday.**





California should seek to capture as many jobs and economic value created through its research and development as is possible. To do this, specific efforts should be made to create conditions under which the technology products produced through research activity are, to the maximum extent possible, also produced in California. While large-scale manufacturing will typically be less expensive to perform elsewhere, smaller-scale advanced manufacturing – particularly in the early stages of the commercialization process where innovation, quality control and access to the laboratory are key – can be done competitively in California.

To sustain an advanced manufacturing base, the State needs to create a business environment in which production is profitable. Since the Manufacturers Investment Credit expired in 2004, California is one of only three states in the nation to tax the purchase of manufacturing equipment, thereby imposing a 6% penalty<sup>38</sup> and creating a major disadvantage for California-based businesses versus those located in other states and countries. A sales tax exemption for manufacturing equipment would benefit all California manufacturers, but could be targeted specifically at leading sectors, such as nanotechnology, that the State has a special interest in nurturing.

**Action: California should take an important step to level the business playing field, particularly for early-stage commercial products, by restoring the exemption from sales tax for the purchase of capital equipment.**

Application-specific development funds support collaborative research by focusing on its division among universities, national laboratories and private entities. Under the terms of such funds, universities conduct the basic research, national laboratories undertake the developmental work, and private companies conduct market-oriented research.

**Action: The State of California should make effective use of application-specific development funds to support collaborative nanotechnology research and encourage product commercialization in such critically important areas as energy, the environment, security and health.**



## RECOMMENDATION 2: BRIDGING THE INNOVATION/COMMERCIALIZATION GAP

The innovation/commercialization gap, metaphorically known as the ‘valley of death’ in technology commercialization terms,<sup>39</sup> describes the gap between funding for basic research and private funding for commercialization activities. While nanotechnology will enable major societal and economic benefits to many industries, much of the technology today is still high risk from an industrial commercialization point of view. New approaches are needed to address these risks across stakeholders and thereby bridge this innovation/commercialization gap in order to realize economic gain.

It is not only a lack of funding that creates the innovation/commercialization gap, but also a lack of communication, commercialization skills, and shared incentives among the innovators, their commercialization advocates, and the private investor community that finances these innovations into commercial entities. These parties – innovators, advocates, and private investors – often have divergent priorities that keep innovations from moving smoothly forward towards commercialization.

Innovators from research universities are generally focused on basic research and discovery, in alignment with the stated goals of their major funding sources. These pioneers typically move from concept to concept based on personal interest and a pioneering desire to be first to identify how things work. Discovery does not necessarily translate into the researcher’s desire or ability to build the innovation to a useful prototype or to commercialize it. In many cases, it is entrepreneurial researchers – most often graduate students and post docs – who act as technology transfer agents, furthering developing innovation into commercial products. Even so, these innovators often lack the experience, skill and market savvy to successfully commercialize innovations. Further, the culture and mandate of the research institution often influence whether entrepreneurship and technology transfer are valued.



Innovators at national laboratories go beyond basic research and develop prototypes and field-deployable solutions for government research application priorities. Accordingly, these researchers often possess the skills for demonstrating solution robustness and scalability, but not necessarily for addressing commercial markets. Innovators at corporate research units excel in the development and launch of new products and solutions, but can only take on levels of investment risk commensurate with their obligations to shareholders for near- and longer-term business success and often closely associated with existing business lines.

Advocates – technology transfer offices, business development staff and non-profit technology commercialization centers – are often chartered to help move innovations from the research lab to the commercial world. The most effective advocates focus on doing ‘what is best for the technology’ in helping it find its way to the commercial world.<sup>40</sup> These advocates, primarily Offices of Technology Licensing (OTL’s), have multiple tools at their disposal to help market, coach, and transact these technologies into the public domain. The best OTL’s often employ seasoned professionals who have entrepreneurial or corporate backgrounds that enable them to assist the innovators and to empathize with the ‘customers’ of the innovation – start-ups and corporations. These OTL’s are treated not as cost centers, but as service providers that build the foundation of the university community. They have the leverage to receive equity in lieu of license fees to better align interests between the innovation centers and the customer.

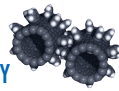
In addition to providing advocates, leading technology commercialization universities provide organic reinforcing activities, community building, and mentoring that foster entrepreneurship. At Stanford,<sup>41</sup> ‘case teams’ of technology, law and business students create business plans, protect intellectual property, and seek funding to move research out of the lab, accelerate its market focus and increase its likelihood of acceptance by the private investing community. Similarly, MIT students have created the \$50K ‘Entrepreneurship Competition’<sup>42</sup> providing educational resources, team building, and venture capital coaches to teams of students who wish to build companies out of technologies.

Unfortunately, most university OTL’s have not adopted the practices of the best innovation centers. By following policies that are intended to protect the innovation center from any potential pitfall of the innovation, many advocates follow policies that cause them to act as barriers to the commercialization process. Too often, university OTL’s are overly aggressive about the value of their intellectual property, when in fact an over-priced license may encourage potential licensees to fight the validity of the patent in court in hopes of avoiding licensing fees altogether. Others follow policies of concentrating their effort on what they perceive as the most valuable innovations and not the broader portfolio. Unfortunately, this approach limits the amount of exposure that many innovations need to find their way to commercial partners. This approach also often imposes high royalty hurdles, further preventing a broader set of commercialization partners from attempting to license the innovation.

One of the most critical success factors for innovations moving from concept to the marketplace is having an application or market-focused leader early on in the commercialization and fundraising process. At venture funds, such a person is an executive entrepreneur in residence, a seasoned CEO or entrepreneur who can scale from research lab to start-up company. Venture capitalists will often not make investments until an appropriate person is identified or can be recruited to the company. It is therefore critical that advocates find ways to attract seasoned entrepreneurs to help build companies out of their innovation centers. Additional funding and incentives can help attract appropriate talent.

Private investors – venture capitalists, angel investors and corporate investors – provide the core risk financing to start-ups. Due to many structural changes in the post ‘dotcom bubble,’ most of the seed and early-stage funding has migrated away from start-ups commercializing technologies immediately out of innovation centers. These structural changes have increased the amount of capital deployed per partner, thereby diminishing the incentive to invest small amounts of money into seed-stage companies. The complexity of nanotechnology also requires a broader and deeper skill set than most venture capitalists retain within their firms. Venture capitalists prefer to fund companies that have already developed prototypes, manufacturing capabilities, a complete management team, and a customer pipeline – and, therefore, have already overcome many risks typically associated with seed-stage investments.

The result is a decreasing pool of commercialization funding available for what are perceived to be high-risk projects. A recent data set published by PWC/Moneytree<sup>43</sup> confirmed that the amount of seed- and early-stage venture capital investment has fallen sharply from its historic level of 15-20 percent to approximately one percent of all venture capital dollars committed in 2004. One solution for addressing this would be to allocate state alternative investment management funds, like CalSTRS<sup>44</sup> and CalPERS,<sup>45</sup> to seed-stage nanotechnology venture capital funds (see ‘California Innovation Initiative’ below).



Overall, in order to close the innovation/commercialization gap, efforts need to be taken across all stakeholders. From a funding perspective, it is essential to extend applied research funding to the development of prototypes and to encourage private investment earlier in the prototype development cycle. The outcome would be to help accelerate the commercialization of nanotechnology and encourage other stakeholder investments.

**Action: The State of California should provide applied research matching funds to innovation centers in conjunction with private investment. The approach used could be modeled after the UC Discovery Grant<sup>46</sup> and national lab CRADA programs.<sup>47</sup>**

Small Business Innovation Research (SBIR) grants accelerate the commercialization of nanotechnology by providing matching funds to start-ups. The receipt of such awards and funding also helps to attract leveraged corporate, private or government funds.<sup>48</sup>

**Action: California should launch a State-based Small Business Innovation Research program modeled on the federal one.**

Licensing and intellectual property processes at California universities and State-based national labs should be based on 'doing what is best for the technology' by addressing metrics, level of activity and resource allocation. This could be achieved by:

- Encouraging OTL's to develop good relationships with venture capitalists and industry, find the best licensees, be flexible in working with companies, avoid conflicts of interest, and expand grant matching programs aimed at promoting nanotechnology R&D that can lead to commercialization.
- Allowing universities to obtain equity rights more than royalties in order to reduce pressure on start-ups for early business returns. The licensing system fails whenever a technology goes unlicensed because of financial issues.
- Managing OTL offices as valued assets – staffing for effectiveness and long-term success, and setting metrics and rewards to attract and retain high-caliber people who can build lasting partnerships with private industry and execute agreements with valued judgment, negotiation skills, accountability and timeliness.
- Encouraging the four existing California Institutes for Science and Innovations – CNSI, QB3, CITRIS and CalIT2 – involved in nanotechnology research to actively participate in effective technology transfer through establishment and management of OTLs with adequate support from the of California.

**Action: California policy makers should strongly encourage public universities and national labs to institute simple and clear licensing and intellectual property processes that accelerate the transition of ideas from the lab to the marketplace.**

## PROMOTING, MARKETING AND COORDINATING AT THE STATE LEVEL



Despite the visibility and strong industrial base of its Silicon Valley, Los Angeles and San Diego high-tech regions, California does not always stand out as a nanotechnology leader. The State is better known for its incumbent industries and research institutions, against which California's nanotechnology infrastructure and assets can be overlooked. The State would benefit from an active promotion and marketing campaign.

The Albany region of New York is a prime example of what can be achieved through effective marketing.<sup>49</sup> Although its original 1998 vision was to become a semiconductor research center, Albany excelled at raising funds, attracting partners, and characterizing itself as a nanotech leader. With an aggressive marketing posture and state support, Albany not only built an impressive infrastructure, it also generated significant media coverage and turned perception into reality by becoming a major nanotech player. Clearly, high goals can be achieved if a region acts cohesively and obtains state support.

Since many regions are competing in the nanotech race, it is particularly important for California's high-tech regions to take advantage of their unique assets to promote themselves in ways that other regions cannot. The major technology and trade shows have already nucleated in California. For nanotechnology, California should also strive to be ground zero. But attracting attendees to stand-alone nanotechnology conferences is becoming increasingly difficult with an overcrowded offering of such events. California must develop unique and noteworthy events to differentiate itself and attract attendees.

**Action: California should promote and market itself as a world and the U.S. nanotechnology leader by hosting large, regionally focused, weeklong events. These 'Nano Weeks' would encompass a wide variety of focused activities spread across California's high-tech regions with nanotechnology assets and infrastructure.**

Projected activities might include open houses at regional research institutions, nanotech conferences, and marketing presentations by local nanotech start-ups to prospective investors. By offering week-long events structured in this manner, California could take advantage of its abundant university and government labs and leading-edge start-ups to generate greater awareness for its resources and infrastructure in contrast to other, less well-equipped regions across the nation.

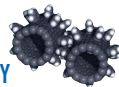
An important anticipated outcome of this type of event would be to establish California's international reputation as the center for nanotechnology. This would make California an 'attractor' for external capital and international workforce, both ingredients that have been key ingredients in the State's past success in developing new technologies. Nano Weeks would also serve to further develop nanotechnology communities within California's high-tech regions, educate the public about the tremendous benefits of nanotechnology, and encourage youth to consider careers in science and engineering.

Although California has traditionally been characterized by a culture of competition, rather than cooperation, domestic and international challenges for nanotechnology supremacy have mandated the need for a comprehensive statewide collaborative marketing strategy for California.

**Action: California should empower existing state and regional organization(s), such as the Bay Area Science and Innovation Consortium (BASIC),<sup>50</sup> or create new organizations, to lead the promotion and marketing of California's nanotechnology assets.**

While an external marketing campaign may bring companies and benefits into California, efforts within the State to foster the sharing of information among existing California businesses and start-ups is also important. Thus sharing can promote clustering, improved infrastructure access, more efficient resource utilization, and enhanced business practices.

One solution is to develop a 'Nano Portal' to bring the world of nanotechnology directly in contact with end-users. The portal design could incorporate a systematic classification or taxonomy and 'nodes' that would contain information about regional laboratories, incubators and workspace, resource skills availability, core capabilities, points of contact and accessibility of the university and national lab systems.



A Nano Portal is an excellent enabler for business success. It would be an ideal forum to advertise incubator and infrastructure resources, thereby facilitating the sharing of resources for increased efficiency. It would also serve as a type of ‘Yellow Pages’ through which information about nanotechnology research, development and infrastructure could be easily accessed. The portal would provide information on issues of concern, such as intellectual property and ownership, access terms and conditions, and product liability insurance.

To create a successful and effective Nano Portal is a major task requiring specialized capability and unbiased judgment. It is advisable to entrust its development and operation to a body that owns no vested interest other than to foster the growth and well being of California business as a whole.

**Action: The State should sponsor a California ‘Nano Portal.’ It should empower an entity with membership from across the spectrum of major California businesses, Federal and State agencies, and academic institutions, such as BASIC, to develop and maintain the Portal. Universities, national labs, consortia and private industry should be enlisted to cooperate and maintain their individual content.**

California’s foundation and culture are built on entrepreneurship and independence. Nevertheless, an innovative and independent approach to technology poses challenges to statewide marketing and promotion efforts, and leaves California vulnerable in the federal funding sweepstakes. Although California receives substantial federal funds, including funds through the Small Business Innovation Research program, the level of federal fund still falls below that of several other states when considered as per capita.<sup>51</sup> Lacking statewide coordination of efforts in California, the pursuit of federal funding is typically left to the uncoordinated activities of individual research entities.

**Action: California should develop a coordinated, state-led effort to pursue federal funding opportunities. This could be accomplished through an existing regional or State organization or the chartering of a new organization empowered to achieve this goal.**

As the most populous state in the nation, California has both a compelling need for coordination and the political muscle to affect funding decisions. Since state-level coordination and political pressure clearly make a difference in the competition for federal funds, it is imperative that California recognizes its vulnerabilities and takes advantage of its strengths through a coordinated approach to the pursuit of federal funds.



## RECOMMENDATION 4: LAUNCHING A ‘CALIFORNIA INNOVATION INITIATIVE’

California is one of the few regions in the world that has strong assets in bio, info and nanotechnologies. This is important because the convergence of those technologies in one location can create a ‘virtuous circle’ of innovation. For example, nanotechnology benefits from, and contributes to, advances in biotechnology. Nanotechnology may also be used for early detection of disease, faster drug discovery, and ‘smart’ anti-cancer drugs with fewer side effects.<sup>52</sup> In turn, advances in biotechnology, such as ‘directed evolution.’ could create viruses capable of assembling nanoscale building blocks into complex nanosystems. Converging technologies may also be used to address major societal challenges, such as the development of clean energy to reduce U.S. dependence on Middle Eastern oil and lower the emission of greenhouse gases.

However, California has not articulated a strategy for establishing a clear leadership position in the convergence of bio, info, and nanotechnologies. California is one of the few regions in the world that could do so, due to existing strengths such as our world-class research universities and national labs, plentiful venture capital, specialized business services for start-ups, and vibrant clusters in biotechnology and information technology. Establishing California’s leadership in the convergence of bio, info, and nanotechnologies would fuel the next wave of economic growth and job creation, and help address major economic, societal and quality-of-life issues.

The BRTFN recommends the launching of a ‘California Innovation Initiative’ as one key component of a strategy to ensure the State’s leadership in convergent technologies.





Such an initiative should provide full funding for the four California Institutes for Science and Technology – QB3, CNSI, CITRIS and Calit2. To date, the State has provided \$400 million in funding for construction of the institutes, but virtually no operational funding. State operational support of \$10 million per institute per year (with a 1:1 matching requirement from industry and federal research grants), would dramatically increase their effectiveness. This would help the institutes to:

- Quickly launch multidisciplinary research initiatives in bio, info and nano-technologies. It often takes years for a team of researchers to persuade a federal science agency to fund a particular idea. Small amounts of seed funding would allow researchers to begin work much sooner. Researchers could then use their preliminary results to compete more successfully for additional federal funds.
- Support shared facilities for cutting-edge research in bio, info, micro and nanotechnologies. Equipment and facilities for 21<sup>st</sup> century research, such as e-beam lithography, transmission electron microscopes, magnetic resonance imaging and mass spectrometry, are becoming too expensive for individual faculty members or small companies to afford. Well-equipped shared facilities with trained staff would increase the productivity of both California researchers and companies.

**Action: The California State Legislature and the governor should provide funds to support the operation of the four California Institutes for Science and Innovation.**

As addressed earlier, many technologies stagnate in the innovation/commercialization gap due to the lack of funding needed to carry them from basic research to product commercialization. Venture capitalist interest may require not just 'proof of principle' but 'reduction to practice' – demonstrating, for example, that high-volume, reliable, cost-effective manufacturing is possible. Other states are providing incentives to increase early-stage investments to fledgling companies. Wisconsin, for instance, offers a 12.5 percent tax credit, Maryland offers 33%, and Kansas recently approved a 50% tax credit for investments up to \$250,000.<sup>53</sup> California should consider a similar tax credit. Another option that might be explored is for CalPERS and CalSTRS to act as a 'funder of funds' for seed and early-stage investments in converging technologies. Obviously, this would need to be done in a way that is consistent with the State's fiduciary responsibilities.

**Action: California should explore ways to increase angel and early-stage investment in start-ups that are commercializing converging technologies.**

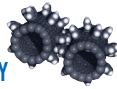
California State agencies should identify areas where they can serve as a 'test bed' or early customer for advanced technologies. The State might be able to use its purchasing power to help validate new technologies or drive them down the learning curve. For example, several California companies are using advances in materials science and nanotechnology to lower the cost of making solar cells. The State could use its purchases of electricity to promote this and other forms of clean energy, which would also support Governor Schwarzenegger's greenhouse gas emission reduction targets.<sup>54</sup> The Governor's 'million solar roofs by 2018' is another example of an effort to stimulate demand.<sup>55</sup>

**Action: California policy makers should encourage State agencies to identify specific areas where the State can be an 'early customer' of new technologies.**

In response to recommendations from the University of California President's Engineering Advisory Council, then-Governor Wilson provided funding to expand the number of UC faculty in engineering and computer science. This, in turn, allowed UC to accept more undergraduate and graduate students and expand the State's high-tech workforce. The State should launch a similar initiative to expand the science and engineering workforce in bio, info and nanotechnologies. This would build on Governor Schwarzenegger's 'California Teach' initiative, which will quadruple the number of annually credentialed science and mathematics teachers by 2010.<sup>56</sup>

**Action: The California State Legislature should take steps to expand California's workforce in bio, info and nanotechnologies. In line with National Academy of Sciences recommendations, the State's California Teach initiative should target the training of approximately 1,200 additional math and science teachers annually.**<sup>57</sup>

California is home to thousands of mid-level professionals with engineering degrees at the bachelors and masters level who are unemployed or significantly underemployed, yet who could be great contributors to future nanotechnology efforts with minimal retraining. Recruiting and training these professionals to teach science



or math in a public school system in California for a period of at least two years would be a cost-effective solution to supporting both an expanded science workforce and improved science education.

**Action: California should provide mid-career professionals with re-educational assistance programs and reduced interest rate loans to receive an education from a California public institution in an emerging field of science and engineering.**



## RECOMMENDATION 5: PREPARING A GLOBALLY COMPETITIVE WORKFORCE

In order to remain fully competitive in the development of nanotechnology industries, California must ensure that it produces, and has access to, the highly skilled workers who will drive such industries. To that end, there is an urgent need to develop and implement a comprehensive and coordinated approach to support educational excellence within the State at all levels, with a particular emphasis on science, mathematics and engineering. California's previous support of a public educational system that spanned K-12 schools, community colleges, and state colleges and universities resulted in a world-class system that was a key factor in the development of the State's high-tech industries. But the U.S. and California education systems have been in decline. A recent assessment ranked California 46<sup>th</sup> out of the 50 U.S. states in terms of educational excellence,<sup>58</sup> and the nation only rated "average" relative to other industrialized countries.<sup>59</sup> Clearly, the State's education system must be improved in order to remain competitive in nanotechnology.

The extensive public K-16 system in California consists of 10 University of California campuses enrolling over 208,000 students; 20 California State University campuses with more than 400,000 students; 109 community colleges enrolling over 2.5 million students, and 9,100 K-12 schools enrolling over 6.5 million students.<sup>60</sup> As a whole, the education system faces financial difficulties in becoming an effective participant that contributes to a technologically skilled workforce. However, there are significant local exceptions that have cultivated outstanding partnerships with industry, and there are exceptional school districts in high-income neighborhoods that consistently produce graduates with advanced math and science skills. Fortunately, these "exception" institutions have already developed excellent model efforts that can be adopted by other institutions.

In the case of the K-12 schools, the State has adopted very rigorous math and science standards,<sup>61</sup> but the reality is that only approximately 15% of the schools have the ability to teach math and science at these high standards.<sup>62</sup> All of the skills required for a high school graduate to enter the workforce or pursue a college degree that would enable that graduate to enter a career in nanotechnology could be taught if every K-12 student in California received one hour each of high-quality instruction in mathematics and science. Currently, the percentage of a typical six-hour school day devoted to science and math is, on average, modest and the math requirement typical of most schools extends only from grades 1 to 10. Within the existing education system, science education is rarely offered for grades 1-5 and, as in the case of math instruction, also rare for grades 11-12.

**Action: The State of California should require at least one hour each of quality math and science instruction daily for all K-12 students. Further, given the present weakness of math and science instruction in K-12 schools in low and middle income neighborhoods, the State should make its highest priority the extensive recruitment and training of new teachers and the professional development of existing teachers.**

In addition to students in comprehensive high schools, there are approximately 460,000 students aged 16 years and older in 73 Regional Occupational Centers and Programs.<sup>63</sup> California supplies guidelines for the development and certification of locally produced courses, and a small number of courses certified for Statewide use. None of these guidelines or courses encompass the area of nanotechnology, although courses in precision machining and similar subjects could be extended and modified to address nanoscience. The San Mateo Biotechnology Career Pathway, for example,<sup>64</sup> has successfully trained vocational students for careers in biotechnology; the development of this curriculum can be a model for similar development of courses in nanotechnology.



**Action: The State of California should encourage California-based high-tech companies to work with the State's Regional Occupational Centers to assist in the creation of training courses that will support technology manufacturing.**

To enhance California's undergraduate education, the State needs to provide incentives for the California State University and Community College systems to develop and offer nanotechnology courses. To do this, faculty at those institutions could be supported to redirect a portion of their teaching duties to prepare new courses in nanotechnology. The development and teaching of undergraduate nanotechnology courses would ensure that California's undergraduate students are competitive in the global workforce.

**Action: The State of California should provide new funds in the University of California, State University and Community College system budgets to provide for the creation of interdisciplinary courses in nanotechnology.**

In the domain of graduate education and research, California's strong support of the University of California system has resulted in ten universities with extensive research capabilities receiving a significant share of the large federal research funds associated with the National Nanotechnology Initiative. These universities, with undergraduate and graduate enrollments of approximately 208,000 students, have built up the fabrication and characterization facilities necessary to achieve the major research advances required to propel nanotechnology forward. This is also true for the major private universities in California, such as Stanford, Cal Tech and the University of Southern California (USC). Faculty at these universities have developed a significant number of nanotechnology classes that are now available to both graduate and undergraduate students. Three new institutions are also under construction; the California NanoSystems Institutes (CNSI) at UCSB and UCLA, funded by the State of California, and the Molecular Foundry at the Lawrence Berkeley Laboratory, funded by the US Department of Energy. These facilities are important in keeping California at the forefront of nanoscience because of their state-of-the-art research capabilities and their leadership in promoting interdisciplinary research.

**Action: The Federal government should continue to support the NNI, and should monitor its procedures so as to minimize visa delays and other potential barriers to entry in order to continue to attract talented foreign students to our universities.**

The State of California is already reaping the benefits of its investment in the construction of the CNSI at UCSB and UCLA in the form of increased nanotechnology conferences, classes and outreach programs even though the buildings are not yet ready for occupancy.

**Action: As part of the proposed 'California Innovation Initiative,' the State should fund the operation of the CISI/CNSI centers so that staff and faculty can focus on nanosystems research. The State should also provide line-item funding to the public university and community college systems to support development of new, interdisciplinary courses for the proposed retraining of mid-career professionals.**

In terms of informal education, the information and outreach provided to the public and schoolchildren in museums, community centers, after-school programs and the media seems to be supported almost entirely by private and federal funds. The separate entities rarely appear to cooperate/collaborate, but this trend may change with the NSF award of a \$20 million, 5-year grant to create a Nanoscale Informal Science Education (NISE) network that includes the San Francisco Exploratorium.

**Action: The State of California should leverage the investments and work of NISE to accelerate the dissemination of NISE-created events, materials and exhibits to other museums and institutions in California.**

California-based national labs have a knowledge base and capabilities relevant to the creation and deployment of user-friendly nanotechnology exhibits.

**Action: The State of California should encourage its federal labs and other technical organizations to investigate the possibility of forming a statewide collaboration of California science museums, and use their expertise to assist in the development of appropriate nanotechnology exhibits for school children and the general public.**



## RECOMMENDATION 6: UNDERSTANDING AND COMMUNICATING THE ETHICAL, ENVIRONMENTAL AND SOCIETAL IMPLICATIONS OF NANOTECHNOLOGY

Nanotechnology holds great promise for clean energy, environmental monitoring and remediation. The potential rewards are enormous, but environmental applications of nanotechnology are still in their infant stages and there are also currently unknown, potential risks. As the CEO of Dupont, Chad Holliday, and the President of Environmental Defense, Fred Krupp, recently concluded in a joint editorial, “An early and open examination of the potential risks of a new product or technology is not just good common sense — it’s good business strategy.”<sup>65</sup>

Public outreach and interaction is critical in order to avoid repeating the controversies associated with genetically modified organisms. This effort is particularly important in California, where environmental issues are taken more seriously than in many other regions. Polls show that the public is excited about the potential of nanotechnology but also concerned about the environmental and human health risks associated with nanotechnology; erosion of privacy from nanotechnology-based sensors; and economic disruption of existing industries and jobs.<sup>66</sup>

The State of California must take steps to: understand and effectively manage the environmental and human health risks of nanotechnology; provide residents with access to credible information on benefits and risks; and facilitate societal acceptance of the commercialization of safe, productive and appropriate nanotechnologies. The State has a variety of agencies and tools at its disposal to accomplish these objectives.

Nanotechnology has great promise to lower the cost of cleaning up environmental contaminants. The California Environmental Protection Agency (Cal/EPA) can be a powerful advocate in promoting applications of nanotechnology for environmental remediation and sensing. One example, the use of iron-based nanoparticles to remediate trichloroethylene ground water contamination, is an active area of research and has direct application to state ground water contamination problems. Another potential use for nanotechnology is in the development of compact, low-cost, ultra-sensitive sensors to measure air and water quality, monitor fuel leaks from underground storage tanks, and detect chemicals from landfill gas. Cal/EPA should form partnerships with federal agencies (like the Defense Advanced Research Projects Agency, Department of Homeland Security and U.S. EPA) to track ongoing research and encourage the development of technologies for environmental uses.

**Action: Cal/EPA should promote environmentally beneficial applications of nanotechnology through research, pilot projects and field trials.**

Early communication between the State of California and nanotechnology manufacturers would go a long way in helping to avoid any unanticipated, negative environmental consequences of nanotechnology that could potentially emerge.

**Action: Cal/EPA should negotiate an agreement with state nanotechnology manufacturers that could be the basis for information exchanges and problem solving related to responsible stewardship of nanotechnology products.**

It is possible that some of the same features of nanomaterials that make them unique (e.g. small size, high surface area to volume ratio, high reactivity) may also have negative consequences for human health. Cal/EPA and the Department of Health Services should dedicate resources for tracking and analyzing emerging health data concerning nanotechnology so that preventative action may be taken before problems develop. Other agencies should also be involved, as necessary and appropriate.

**Action: Cal/EPA and the Department of Health Services should track health data about nanotechnology so appropriate actions can be taken before problems develop.**

There are many promising applications of nanotechnology, one of which is the development of safety monitors that are less expensive and more accurate than current models. Cal/EPA regulatory programs should purchase monitors that utilize nanotechnology as they become available, and also collaborate with others to develop analytical methods that use nanotechnology.

**Action: Cal/EPA should actively encourage responsible environmental applications of nanotechnology.**



It is important that Californians have a good understanding of nanotechnology, its impact, significance and consequences. To assist in educating the public, California should institute initiatives to: (1) brief the creative talent associated with the movie and TV industry on beneficial applications of nanotechnology; (2) develop a compelling, inspirational Digital Cinema or IMAX educational film about nanotechnology; (3) develop a nanotechnology video game; and/or (4) create additional museum exhibits on nanotechnology like those in the Lawrence Hall of Science's 'NanoZone'<sup>67</sup> or the San Francisco Exploratorium's 'Visualization Laboratory.'<sup>68</sup>

**Action: California should leverage its strength in entertainment and science museums to increase public awareness and understanding of nanotechnology.**

Nanotechnology has the potential to make alternative energy more competitive with fossil fuels, and California has the capability to establish a clear leadership position in clean energy. To that end, State and local governments should:

- Expand tax credits to encourage rapid adoption of alternative energy;
- Make installation and alternative energy equipment permitting exempt from siting and operational restrictions, property deed restrictions and planned unit development C.C. & Rs (covenants, conditions and restrictions);<sup>69</sup>
- Make permit applications for alternative energy installation and operation a priority for each locality;
- Provide incentives to city and county governments to adopt alternative energy installations for their own power needs; and
- Require utilities serving California to buy back excess electric power produced from alternative fuels at the highest rate charged for each class of user (residential, commercial and industrial).

**Action: The State of California and local governments should encourage widespread and rapid adoption of energy from alternative sources via tax and regulatory policy.**

Californians need access to clear, unbiased, credible information about the advantages and disadvantages of nanotechnology. This could be achieved in various ways, including through a model that includes the creation and availability of:

- A public website, including summaries and links to information on areas of public interest. It should include a list of Frequently Asked Questions (FAQ), initially seeded with questions we expect to be asked, and later developed into a list of questions that are most often asked;
- A credible spokesperson, from outside industry, to interact in a timely manner with the media; and
- A Board of Advisors including one or more representatives from groups with an environmental focus to ensure that these environmental views are included. These Advisors should, to the greatest extent possible, be relatively unbiased (neither pro nor con) toward nanotechnology-based industries.

**Action: One or more California academic institutions or non-profits should be chartered to establish and make available credible, independent sources of information about nanotechnology.**

One potential lead institution for such an endeavor is UC Santa Barbara's Center for Nanotechnology in Society,<sup>70</sup> an NSF-funded Nanoscale Science and Engineering Center. The center could help scientists, scholars, policy makers, and the public better understand the societal implications of nanotechnologies, particularly as they unfold over the next decade. The center could also play an important role in stimulating unprecedented interdisciplinary collaboration across the nation among faculty members and students in the social sciences, humanities, physical and life sciences and engineering. The planned UC Bio-Info-Nano Research and Development Institute (BIN-RDI) in the Ames-based NASA Research Park could also serve as such a center.





## RECOMMENDATION 7: ADDRESSING BUSINESS CLIMATE CONCERNS IN CALIFORNIA

High costs associated with energy, workers compensation, corporate taxes and numerous other factors put California manufacturers at a competitive disadvantage compared to enterprises based in other locations. This makes California's business climate less conducive to attracting and retaining private companies, particularly the kinds of small businesses and start-ups that typically dominate emerging nanotechnology industries.

**Action: While this is a complex problem with no rapid or easy fixes, California policy makers should evaluate alternatives for improving the business climate in the State and leveling the playing field for California-based businesses. This includes income tax holidays and sales tax exemptions (as discussed earlier in this report).**

California businesses are also subject to a host of federal and state regulations, some of which place excessive burdens and significant hardships on small firms and start-ups. The Sarbanes-Oxley (SOX) regulations,<sup>71</sup> for instance, require even small public businesses to store huge volumes of all kinds of data for long periods of time subject to extremely rapid retrieval. While intended to prevent fraudulent business practices and questionable accounting methods, SOX compliance is estimated to cost even the smallest of public companies on the order of \$1 to \$2 million annually.<sup>72</sup> This requirement is tantamount to a hidden tax, which has caused many formerly profitable small public companies to lose money. It also harms start-ups because it reduces the opportunity for initial public offerings and mergers and acquisitions. Ultimately, under this system, venture capital funding shifts to later-stage companies, start-ups struggle, and promising nanotechnologies fail to bridge the innovation/commercialization gap and may never find their way to market.

**Action: State and Federal policy makers should re-evaluate business regulations such as SOX while being attentive to these burdens and how best to create a more business-friendly climate, particularly for small companies and start-ups commercializing emerging, disruptive technologies like those in nanosciences.**

Finally, Small Business Innovation Research contracts can be a significant business stimulant, particularly for California's nanotechnology start-ups. However, current rules prevent many venture capitalist-backed start-ups from taking advantage of SBIR opportunities. Start-ups in which venture capital firms own more than 50 percent of the equity should be qualified to bid on SBIR contracts. This is especially the case when two or more firms jointly own more than 50 percent of the equity. These venture-backed start-ups should still meet all other tests for SBIR awards. This is an important issue for California since a large portion of venture capital-backed start-ups are located in the State, and most nanotechnology start-ups stand to benefit from the receipt of SBIR awards.

**Action: The State of California should work with its Federal legislative delegation to explore avenues to have the current SBIR regulations changed to permit venture capital funds with majority ownership of start-ups to qualify for SBIR awards.**

## RECOMMENDATION 8: EMPOWERING ORGANIZATIONS TO CONTINUE THE BRTFN MISSION



Emerging technologies often have a profound effect on the U.S. economy and national security. This was certainly the case with information technologies, hence the federal government's critical role in development of the Internet. Developing nanoscience and nanotechnology is just as fundamental, if not more so, to the future of our country.

In the case of the Internet, the Information Science Institute<sup>73</sup> was established to assist the federal government in fostering an effective program of innovation with academia, the private sector and the national labs. The promise of sustaining the work of the BRTFN lies in the ability of organizations that have a vested interest in the regional and statewide development of nanoscience and nanotechnology to collaborate over the next several years. Consequently, there is now a need for effective nanotechnology consortia to play a key role in furthering the mission of the BRTFN. This will mitigate risks as we seek to develop nanotechnology-enabled solutions that address U.S. national defense interests, healthcare needs and technological competitiveness, among other areas.

There are two collaborative approaches that could significantly increase the likelihood of promoting and sustaining California's competitive edge in emerging nanotechnologies and maximizing the economic return from technology transfer and commercialization in nanotechnology. The first of these approaches is the promotion of public/private collaborative research and commercialization efforts, and the second is the follow-on promotion of the mission and tracking of the action agenda recommended by this report.

The economic returns from nanotechnology innovation would be heightened by the creation of two or three regional consortia to promote collaborative research efforts by encouraging companies, universities, national labs and other participating entities to join together to select research topics and directions that offer the greatest commercial potential. This type of collaborative relationship, plus the enhanced prospect for commercialization, is likely to increase the amount of corporate and federal funding available for high-tech research in California.

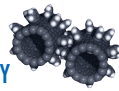
From an investor's perspective, the participation of a number of companies and funding sources (private, federal, state and academic) results in risk mitigation, as a large number of partners share in the risks as well as the rewards of an improved technology innovation process. The critical mass of researchers and their increased iterations with potential end users also qualitatively increases the chances of successful commercialization.

The federal government plays the dominant role in providing seed investments in technology development by funding the research portfolios of the different federal agencies. Industry consortia – by bringing additional parties to the proposal and access to other sources of matching funds – are better able to obtain federal funding, thus further enhancing the 'virtuous cycle' of research, innovation and commercialization.

Three efforts, currently in the early stages of development, may be appropriate to use as the basis for such consortia. In northern California, there are two such efforts. One is the University of California-sponsored BIN-RDI in NASA Research Park.<sup>74</sup> The second is the Nanoelectronics Research Institute promoted by the San Jose based Semiconductor Industry Association. In southern California, two major universities, UCLA and UCSB, have joined forces to build the California NanoSystems Institute. A key part of CNSI's mission is to support collaboration among California's university, industry and national lab scientists. Current partners include Hewlett Packard, Intel, SGI, Sun Microsystems, Rockwell Scientific, Amgen, Affymetrix, Accelrys and Agilent Technologies.

Another example from southern California is the Network T2 consortium of 17 California universities and research institutions focused on driving innovation through more effective technology transfer. The consortium, under the management of LARTA Institute,<sup>75</sup> includes Cal Tech, UCLA, USC, UCSD, UCSB, UCSC, UCI, Cal State Fullerton, Cal Poly Pomona, San Diego State, LA Biomed, Cedars-Sinai and the City of Hope. A leading hub for moving new technologies into the market, it has business affiliations with DuPont, Hewlett-Packard, Genzyme, Invitrogen, and others.

Developing additional industry partnerships as one legacy of the BRTFN will improve the ability of the proposed consortia to attract significant federal research funding to the state. This, in turn, will go a long way in establishing California as the recognized national focal point for pre-competitive nanotechnology development.



In addition, these consortia could provide a key link between public policy and economic development by encouraging better technology transfer and broader industrial participation. From a public policy perspective, these consortia could couple to the state government through the economic development responsibilities resident in the Business, Transportation and Housing Agency.<sup>76</sup>

**Action: The state should empower one or more regional consortia to continue efforts to build partnerships and collaborations encompassing the breadth and diversity of California institutions involved in nanotechnology research and commercialization.**

To ensure that the work of the BRTFN is translated from rumination to reality, a statewide organization should be empowered to take responsibility for carrying on the BRTFN mission. The objectives would be to continue the process of developing strategies beneficial to ensuring California's leadership in nanotechnology and to monitor and facilitate progress on recommendations previously advanced. Additional objectives would be to leverage existing efforts, thereby avoiding replication, and to coordinate the work of other organizations or associations, as appropriate.

For optimum effectiveness, the organization should have the following characteristics:

- a non-governmental, 501(c)(3) non-profit that can provide neutral oversight and qualify for foundation grants;
- a cross-sector collaboration or consortium of representative stakeholders (such as research institutions, industry, venture capital, government, academia, chambers of commerce and unions); and
- the capability to work throughout the State to develop and sustain a bold initiative and work plan, to propose and advocate for legislation and public policies that promote nanotech (research to market), and to create an effective plan that informs and educates all stakeholder groups, the public and the media.

The California Council on Science and Technology (CCST) provides a model of neutral promotion of state science and technology. In that mold, two organizations in the Bay Area are strong candidates around which an effective regional consortium could be built: the Bay Area Science and Innovation Consortium (BASIC) and the Technology Convergence Consortium (TC2), under management of the Joint Venture: Silicon Valley network. Both offer neutral positions, strong track records, and representation from across private companies, non-profits, government, academic institutions and national labs.

**Action: Empower a non-government consortium, based around an existing non-profit, and provide public support and resources to carry forward the work of the BRTFN.**



## FINAL THOUGHTS

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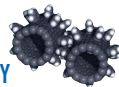
California is poised to be a world leader in nanotechnology. Our State has an exceptional existing infrastructure, an unparalleled history of technological success, and an entrepreneurial and innovation culture. Our resources and advantages, as illustrated by our success in semiconductors and biotechnology, are manifold, but we must continue to be proactive in achieving leadership in nanotechnology.

Emerging nanotechnologies are extremely disruptive, threatening complete upheaval of the industrial and economic landscapes. This opens the door to intense competition – both domestic and foreign – in a technological and economic challenge of unparalleled magnitude, significance and consequence.

California will not achieve a world leadership position in nanotechnology by accident, but rather, through a strategic and coordinated effort specifically targeted to achieve success. We must quickly and effectively implement an aggressive, action-oriented agenda to ensure California's continuing role as a leading world economy in the emerging nanotechnology era. If we do not take action now, another U.S. region or foreign country will assume a leadership role and with it, reap the extensive economic, social and technological benefits accompanying these burgeoning new industries.

There is no question that a nanotechnology revolution of unprecedented magnitude and economic impact is already well underway. Therefore, it is absolutely vital that the State of California immediately step up to the leadership challenge this revolution poses.

The Blue Ribbon Task Force on Nanotechnology submits this report to State Controller Steve Westly and Congressman Mike Honda as both an urgent call to action and a suggested blueprint for achieving California's nanotechnology destiny.



## Acronyms

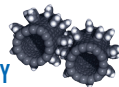
BASIC	Bay Area Science and Innovation Consortium
BIN-RDI	Bio-Info-Nano Research and Development Institute
BRTFN	Blue Ribbon Task Force for Nanotechnology
Cal/EPA	California Environmental Protection Agency
CallT2	Center for Telecommunications and Information Technology
CalPERS	California Public Employees' Retirement System
CalSTRS	California State Teachers' Retirement System
C.C. & Rs	covenants, conditions and restrictions
CEO	Chief Executive Officer
COINS	Center of Integrated Nanomechanical Systems
CITRIS	Center for Information Technology Research
CMOS	Complementary Metal Oxide
CNSI	California Nanosystems Institute
CRADA	Cooperative Research and Development Agreement
DARPA	Defense Advanced Research Projects Agency
DHS	Department of Homeland Security
EPA	Environmental Protection Administration
FAQ	Frequently Asked Questions
FCRP	Focus Center Research Program
IMEC	Interuniversity MicroElectronics Center
K-12	Kindergarten through 12th Grade
K-16	Kindergarten through 4 years of college
LBNL	Lawrence Berkeley National Lab
LLNL	Lawrence Livermore National Lab
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NNI	National Nanotechnology Initiative
NRI	Nanoelectronics Research Initiative
NRP	NASA Research Park
NSF	National Science Foundation
OTL	Offices of Technology Licensing
PWC/Moneytree	Price Waterhouse Coopers/Moneytree
QB3	Quantitative Biomedical Research
R&D	Research & Development
SBIR	Small Business Innovative Research
SNL	Sandia National Laboratory
SOX	Sarbanes-Oxley Act
UARC	University Affiliated Research Center
UC	University of California
UC Berkeley	University of California Berkeley
UCD	University of California Davis
UCI	University of California Irvine
UCLA	University of California Los Angeles
UCSB	University of California Santa Barbara
UCSC	University of California Santa Cruz



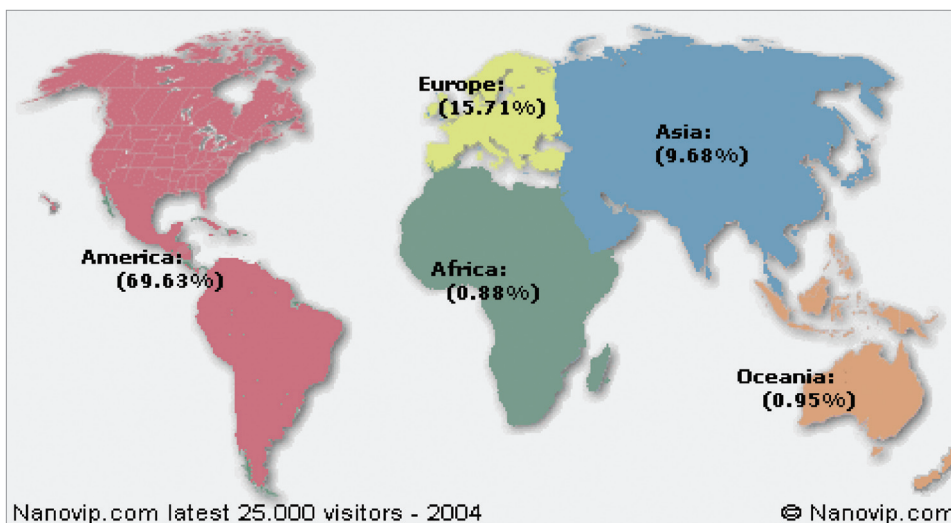


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3. See the White House press release, December 3, 2003 "President Bush signs Nanotechnology Research and Development Act," at: <http://www.whitehouse.gov/news/releases/2003/12/20031203-7.html>
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16. See SGI news release of October 26, 2004. "NASA's Columbia Supercomputer is World's Fastest," at: [http://www.sgi.com/company\\_info/newsroom/press\\_releases/2004/october/worlds\\_fastest.html](http://www.sgi.com/company_info/newsroom/press_releases/2004/october/worlds_fastest.html)  
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22. Information about the LBNL Advanced Light Source: <http://www.als.lbl.gov/als>
23. See: <http://www-ssrl.slac.stanford.edu/>
24. More info can be found at: <http://www-cms.llnl.gov/bsnl/index.html>
25. See: <http://www-cms.llnl.gov/about/nscl.html>



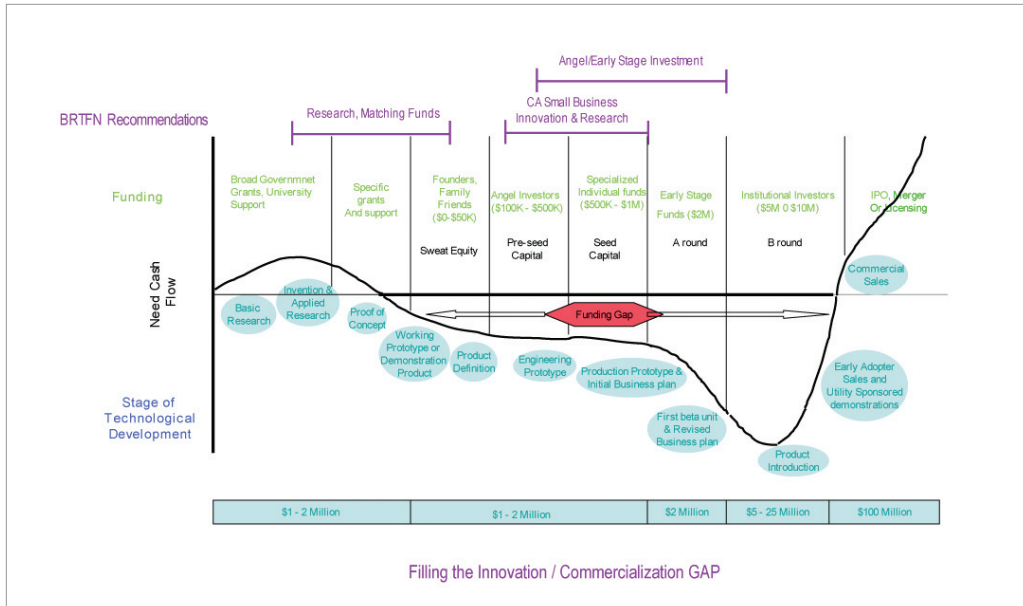
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27. See, for instance, NanoInvestorNews.com, at: <http://www.nanoinvestornews.com>. Map from NanoVIP.com shows percentage of nanotechnology companies world wide. The U.S. leads the pack by a wide margin with 309 nano companies followed by Germany in second place with 32 (NanoVIP 2004), excluding research laboratories, academic structures, organizations, financial institutions, and Mems companies. within the U.S., California leads all states with 89 nano companies, followed by Massachusetts with 35 (NanoVIP 2004).



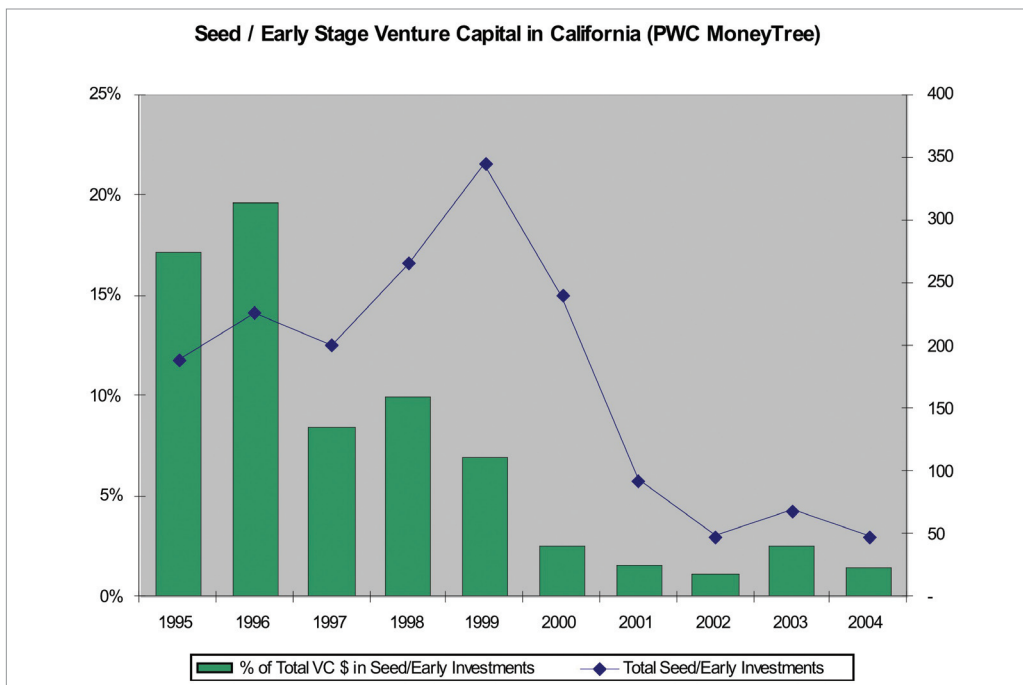
28. See "Our Annual Ranking of Small Tech: Only One First Place But Many Winners," Small Times, March 14, 2005
29. Moore's Law is a rule of thumb in the computer industry about the growth of computing power over time. Attributed to Gordon E. Moore the co-founder of Intel, the most rigorous interpretation of Moore's law holds that the total number of transistors on the cheapest CPU will grow exponentially at a constant rate and that this constant rate produces a doubling every 18 (or 12 or 24) months. This variant oversimplifies a complex history. See: [http://en.Wikipedia.org/wiki/Moore's\\_law](http://en.Wikipedia.org/wiki/Moore's_law)
- For the Intel version, see also: [ftp://download.intel.com/museum/Moores\\_Law/Printed\\_Materials/Moores\\_Law\\_2pg.pdf](ftp://download.intel.com/museum/Moores_Law/Printed_Materials/Moores_Law_2pg.pdf)
30. See "Life Beyond CMOS" as presented at the National Information Devices workshop March 25, 2005, at: <http://istresults.cordis.lu/index.cfm/section/news/tpl/article/BrowsingType/features/ID/74884> and "SIA Launches Nanoelectronics Research Initiative," at [http://sia-online.org/pre\\_release.cfm?ID=343](http://sia-online.org/pre_release.cfm?ID=343)
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34. Further Testimony of George Scalise, President, Semiconductor Industry Association, before the US China Economic and Security Review Commission, "China's High-Technology Development," April 21, 2005.
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36. See: <http://www.sia-online.org> for information about the Semiconductor Industry Association, the sponsor of the Nanoelectronics Research Initiative (NRI).
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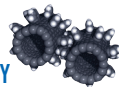
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41. Per private conversation with Mark Lemley, William H. Neukom Professor of Law, Stanford School of Law.
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43. Figure description Seed/Early Stage Venture Capital in California (PWC MoneyTree). Data provided by the PricewaterhouseCoopers/Thomas Venture Economics Survey data from 1995 through 2004.



Additionally, see: <http://www.pwcmoneytree.com/moneytree/nav.jsp?page=historical> for information about PricewaterhouseCoopers Global Historical investments.

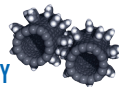


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45. For CalPERS, see: <http://www.calpers.ca.gov/>
46. See: <http://uc-industry.berkeley.edu>
47. Cooperative Research and Development Agreements (CRADAs). The FTTA (Federal Technology Transfer Act) of 1986, Public Law 99-502, codified at 15 U.S.C. 3710 et seq., and further amended on March 7, 1996, by Pub. L. No. 104-113, authorized the CRADA as a new mechanism to encourage the transfer of the results of Federal research and development to the private sector, see: <http://www.osec.doc.gov/bmi/10-18.htm>
48. For information on SBIR/STTR, see: <http://www.sba.gov/sbir/>
49. See: [http://www.albanynanotech.org/News/index.cfm?step=show\\_detail&newsID=204](http://www.albanynanotech.org/News/index.cfm?step=show_detail&newsID=204)
50. Information about the Bay Area Science and Innovation Consortium (BASIC) can be found at: <http://www.bayeconfor.org/basic/>
51. See data from ASTRA, The Alliance for Science & Technology Research in America at <http://www.aboutastra.org> Data were compiled from the following sources: National Science Foundation, U.S. Census Bureau, U.S. Bureau of Labor Statistics, National Venture Capital Association, NASDAQ, U.S. Patent & Trademark Office, Progressive Policy Institute (2003), American Electronics Association CyberStates 2003
52. See, for instance, "Nanocosm: Nanotechnology and the Big Changes Coming from the Inconceivably Small," by William Illsey Atkinson.
53. See: <http://www.ksrevenue.org/taxcredits-angel.htm>, <http://www.bizjournals.com/baltimore/stories/2004/01/19/story7.html>, and <http://www.commerce.state.wi.us/act255/BD-Act255-angelinvestors.html>
54. See: [www.climatechange.ca.gov/climate\\_action\\_team/factsheets/2005-06\\_GHG\\_REDUCTION\\_FS.PDF](http://www.climatechange.ca.gov/climate_action_team/factsheets/2005-06_GHG_REDUCTION_FS.PDF) "California's Greenhouse Gas Emission Reduction Leadership Policy."
55. See: [http://www.energy.ca.gov/releases/2005\\_releases/2005-02-28\\_governor\\_solar.html](http://www.energy.ca.gov/releases/2005_releases/2005-02-28_governor_solar.html) "Governor Schwarzenegger Announces One Million Solar Roofs by 2018."
56. See, for instance, "Irvine receives \$2.5 million to establish endowed chair dedicated to excellence in science and mathematics teaching" at: [http://www.ucnewswire.org/news\\_viewer.cfm?story\\_PK=5044%20-%208.0KB](http://www.ucnewswire.org/news_viewer.cfm?story_PK=5044%20-%208.0KB)
57. See "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future (2005)," The National Academy of Sciences -- Committee on Science, Engineering and Public Policy, the National Academies Press, 2005.
58. See, for instance: <http://www.morganquitno.com/edrank05.htm>  
  
This "Smartest State" analysis was based on 21 factors chosen from Morgan Quitno's annual reference book, Education State Rankings, 2005-2006, with a focus on student achievement, positive outcomes and personal attention from teachers. States are assessed based on how they stack up against the national average.
59. See "New Study Finds US Math Students Consistently Behind Their Peers Around the World," PR Newswire, Nov. 22, 2005, on line at: <http://prnewswire.com/cgi-bin/stories.pl?ACCT=SPIEDU.story&STORY=/www/story/11-22-2005/0004221400&EDATE=TUE+Nov+22+2005,+10:06+AM>  
  
See also: International Comparisons section of "Report: U.S. teachers log most hours" CNN, October 30, 2002 citing Organization for Economic Cooperation and Development study <http://archives.cnn.com/2002/EDUCATION/10/30/us.education.comparison.ap/>
60. Various data about California's K-16 public education system can be found at:  
<http://www.cde.ca.gov> (California Department of Education),  
<http://www.universityofcalifornia.edu/admissions/statistics.html> (University of California),  
<http://www.calstate.edu/> (California State Universities), and  
<http://www.californiacolleges.edu> (All colleges in California).
61. California Department of Education standards for education can be found at: <http://www.cde.ca.gov/be/st/ss/>
62. Personal estimate of Education subcommittee chair, George Castro, based on grant proposal research from 2002.



63. See: <http://www.carocp.org/>
64. See, for instance, "Community colleges eye biotech; industry returns the favor," at [news@nature.com](mailto:news@nature.com): [http://www.nature.com/news/2005/050321/pf/bioent851\\_pf.html](http://www.nature.com/news/2005/050321/pf/bioent851_pf.html)
65. As quoted in the Wall Street Journal, June 14, 2005. See also: <http://www.environmentaldefense.org/article.cfm?contentID=4821> "Environmental Defense and DuPont: Global Nanotechnology Standards of Care Partnership." news release dated October 11, 2005 from Environmental Defense.
66. See, for instance: [http://www.wellcome.ac.uk/doc\\_WTD015760.html](http://www.wellcome.ac.uk/doc_WTD015760.html) "What do the public think of nano?" based on polls conducted for the Royal Society and Royal Academy of Engineering.
67. Check out the LHS's NanoZone at: <http://www.lawrencehallofscience.org/>
68. For information about the Exploratorium, see: <http://www.exploratorium.edu/>
69. See: <http://www.energy.ca.gov/> to learn more about the California Energy Commission.
70. See: <http://www.cns.ucsb.edu/>
71. See the Sarbanes-Oxley Act (SOX) H.R. 3763 107th Congress, 2nd Session at: <http://financialservices.house.gov/media/pdf/hr3763ah.pdf>  
House: 107 H.R. 3763, H. Rept. 107-414, H. Rept. 107-610  
Senate: 107 S. 2673, S. Rept. 107-205  
Law: Pub. L. 107-204, 116 Stat. 745
72. Note that there is some considerable debate over the specific requirements of the Sarbanes-Oxley act. The cost of implementing the requirements has also raised concerns. One key area of cost is the updating of information systems to comply with the control and reporting requirements. Systems that provide document management, access to financial data, or long-term storage of information must now also provide auditing capabilities. In most cases this requires significant changes, or even complete replacement, of existing systems, which were designed without the needed level of auditing details. Costs associated with SOX compliance have proven to be higher than first anticipated. According to the Financial Executives International (FEI), in a survey of 217 companies with average revenue above \$5 billion, the cost of compliance was an average of \$4.36 million. The survey also indicated actual costs of to be approximately 39% higher than companies expected to spend. However, non-compliance comes with an even higher cost in terms of stiffer penalties and jail sentences. See, for instance: <http://en.wikipedia.org/wiki/Sarbanes-Oxley>
73. Information about ISI can be found at: <http://www.isi.edu>
74. See "\$4 million in federal funding secured for two major UCSC research programs" University of California Santa Cruz press release dated November 21, 2005. [http://www.ucsc.edu/news\\_events/press\\_releases/text.asp?pid=785](http://www.ucsc.edu/news_events/press_releases/text.asp?pid=785)
75. See: <http://www.LARTA.org/Services/NetworkT2.asp> for information about the Network T2 Consortium under the management of the LARTA Institute.
76. See: <http://www.bth.ca.gov>





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### **Special Thanks**

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