COLORADO BUSINESS REVIEW

A publication of the Business Research Division
Volume 72, Number 4/5/6, 2006

Overview of Colorado Nanotechnology Roadmap Project

Gary Horvath

Funding Sponsors

Economic Development Administration
Governor's Office of Economic Development and International Trade
Denver Mayor's Office of Business Development
The University of Colorado at Boulder

Project Team

Dr. Mary Ann Roe is currently working part-time with the Colorado Department of Labor.

Karen Eye is a senior research associate with the Business Research Division in the Leeds School of Business.

A Day in the Life of Nanotechnology

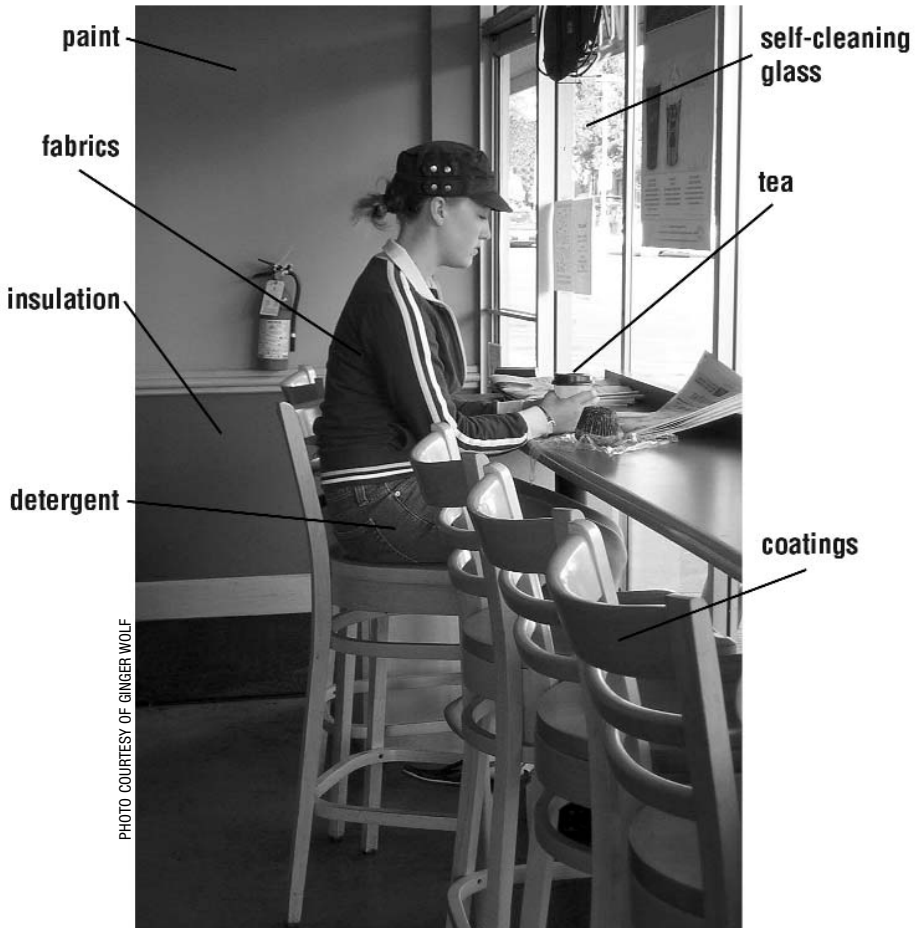

PHOTO COURTESY OF GINGER WOLF

Roadmap Advisory Task Force (RTF)

The project team worked closely with the RTF, which provided input and assistance with completing various project tasks. The RTF was a cross-functional group of individuals representing research, economic development, industry, and workforce development.

Through their combined efforts, it was determined that the roadmap would focus on five functional areas: leadership and resource development, research and technology transfer, workforce development, business growth, and societal implications. Information was gathered from interviews with industry professionals; a series of focus groups for the functional areas; industry, laboratory, and university surveys; strategy sessions; meetings with local nanotech associations; and visits to other states to assess nanotechnology capabilities. Overall, more than 150 professionals provided input.

In developing the plan, the project funding organizations were insistent that it be put together in a way that ensured its successful implementation.

Overall Desired Outcome

The overall desired outcome of the roadmap is to establish Colorado as one of the top 10 states for nanotechnology-based economic

CONTINUED ON PAGE 3

Colorado Nanotechnology Roadmap: It's No Small Matter

This issue of the *CBR* provides a summary of the comprehensive Colorado Nanotechnology Roadmap. The Roadmap was designed with the purpose of leveraging existing nanotechnology investment, assets, research, and human capital in the state to facilitate the growth of the emerging nanotechnology cluster.

An overview of the project is presented on the front page, with highlights of the five functional areas that were identified as essential to Colorado's nanotechnology future on pages 3–6. The photo on page one and the story on this page illustrate how nanotechnology is already used in our everyday lives. A Call to Action appears on page 7.

For more information about this project, visit the Colorado Nanotechnology Alliance web site, www.coloradonanotechnology.org.

Colorado Business Economic Outlook Forum

It's not too early to mark your calendars to attend the 42nd annual Colorado Business Economic Outlook Forum. The half-day event will be held Monday, December 4, at the Marriott City Center Hotel in downtown Denver.

As always, please contact me at 303-492-1147 with any questions or comments.

—Richard Wobbekind

A Day in the Life of Nanotechnology

This brief story illustrates the uses of nanotechnology in our everyday lives.

Mike and Maggie wake up (1) early on a Friday morning to get a strong start to the day.

They get dressed (2) to play tennis (3) at the recreation center. Yesterday, Mike polished and waxed the car (4), and treated the windshield (5). It looks shiny new today.

When they arrive at the tennis courts, Mike and Maggie apply sunscreen (6). Maggie admires the Rec Center's lovely new paint (7) job.

After their game, the couple returns home to prepare for the rest of the day. Maggie cleans and bandages (8) the cut she got on her knee during the game, puts on her make-up (9), and gets dressed (10) to go to work.

Mike works from home, so after breakfast (11), he sits (12) down at his desk to work on the computer (13). Later in the afternoon (14), Mike decides to search online for an anniversary gift for Maggie, and finds a necklace (15) he is sure she will love, at a store nearby. He grabs his bicycle (16) and rides over to check it out.

When Maggie arrives home from work, her elbow is sore from the morning's game, so she puts some pain relief cream (17) on it. She then finds her golf clubs (18) and puts them by the door to take to her lesson tomorrow morning.

Mike arrives home and begins the stir-fry for dinner (19), while Maggie cleans up the house a bit (20).

Over dinner, Maggie tells Mike that she is pregnant (21)! After dinner, they have tea (22), get ready for bed (23) and drift happily off to sleep (24).

1: pillows with silver nanoparticles for their anti-bacterial properties

2: athletic socks with anti-fungal properties; insoles; elbow guard; sports clothing

3: tennis racquets made stronger and lighter by carbon nanotube technology

4: finer particles in polishing and waxing agents reduce scratches to the paint

5: improved water repellence and a barrier that reduces adherence of snow and dirt

6: ultrafine zinc and titanium dioxide particles reflect the sun

7: silica nanoparticles used in anti-graffiti paint

8: wound dressings with an antimicrobial barrier

9: cosmetics

10: stain-resistant pants

11: supplements composed of smaller particles for fast absorption

12: back support pillow

13: computer processor, hard drive, screen

14: air conditioner

15: cultured diamonds

16: carbon nanotube technology in the bicycle frame is lighter and stronger

17: nanotechnology delivery system for quick absorption

18: clubs with nano composite technology; golf balls

19: canola oil with nanodrops to increase absorption of beneficial components; refrigerator

20: vacuum; washing machine; detergent; air sanitizer

21: home pregnancy test

22: nanotech used for increased absorption of tea essences

23: night cream; toothpaste

24: mattress with stain resistance

Roadmap Advisory Task Force

- Rich Bolin
- Dr. Linda Bowman
- Dr. Ellen Fisher
- Michael L. Drapkin
- Preston Gibson
- Booker Graves
- Griff Kundahl
- Dr. Randy Levine
- Dr. Roop Mahajan
- Dr. Arlen Meyers
- Dr. John Oakey
- Dr. Kent Rochford
- Christine Shapard
- Debbie Woodward

OVERVIEW, CONTINUED FROM PAGE 1

development. The success of this Roadmap will be measured by the completion of 70% of objectives of the Colorado Nanotechnology Roadmap within the three-year timeline.

It is important to note that the Roadmap project is more than just the 24-page document that was presented at the rollout held September 18, 2006, as part of the Governor's Tech Week.

The Roadmap provides an analysis of the state's research and company assets. In addition, secondary metrics were identified that the recently established Colorado Nanotechnology Alliance (CNA) can use to chart the growth of nano cluster. A database of companies in other states has also been compiled so Colorado assets can be marketed to these companies. Moreover, the project team met with leaders in other states, which will open opportunities for Colorado to partner with its neighbors.

Finally, future leadership and direction of the nano cluster will be strengthened by the recent hiring of an executive director and the securing of a location for CNA in the Advance Colorado Center.

Why Nano Is Important to Colorado

As part of the study, companies were surveyed to ascertain their involvement in nanotechnology. It was determined that nano R&D being performed by Colorado firms has primary applications in the following industry sectors:

- Electronics
- Aerospace
- Homeland security/defense
- Biomedical
- Energy

Companies are focused on the following research areas (in order of priority):

- Nanomaterials
- Nanoscale devices and systems
- Nanomanufacturing
- Nanoscale phenomena and processes
- Instrumentation, metrology, and standards for nanotechnology

The research for this project identified 75 companies in Colorado that are involved in nanotechnology. These firms are located in 20 cities and 11 counties, and are primarily concentrated in Boulder and Jefferson counties and, to a lesser extent, El Paso County. It is believed that the companies are located in these areas so they can be near the National Institute of Standards and Technology, the National Renewal Energy Laboratory, the Colorado School of Mines, CU-Boulder, and the aerospace and defense industries. Past research conducted by the BRD indicates that over the next 5–10 years the cluster will increase in both size and geographic diversity.

About 47% of the companies are classified as R&D companies as revealed by their NAICS code, while 42% are categorized as manufacturers. As is the case with most emerging technology clusters in Colorado, the companies are small, with a median size of 14.5 employees.

The BRD's work with other clusters indicates that it is relatively easy to develop a list of companies in a cluster and to identify the total employment levels associated with those companies. While that is one measure of a cluster's size, perhaps a more effective measure is the number of technical workers. As part of the research process, about 150–200 full-time and an equal number of part-time technical nano workers were identified. The number of nano researchers and technicians in the universities and federal labs is estimated to total approximately 200.

These employment numbers will be used as a benchmark for developing workforce training programs. Because the companies in this cluster often work in highly specialized areas, it is important to address their workforce training needs because of the cross over with other industries, the fiscal output per nano employee, and the potential growth of the cluster.

Gary Horvath is managing director of the Business Research Division in the Leeds School of Business at CU-Boulder. He can be reached at Gary.Horvath@Colorado.EDU.

CNA Contact Information

Debbie Woodward
Executive Director
Colorado Nanotechnology Alliance
1625 Broadway, Suite 950
Denver, CO 80202

Direct: 303-592-4084
Fax: 303-592-4061

dwoodward@coloradonanotechnology.org
www.coloradonanotechnology.org

Nano Roadmap:

LEADERSHIP

Brian Lewandowski

Nanotechnology has proven applications in nearly every industry, including aerospace, defense/homeland security, biomedicine, electronics, and energy—industries vital to Colorado. With proclamations of a $1 trillion global nanotechnology market by 2015, a National Nanotechnology Initiative currently doling out billions in research and development grants annually, and an expected industry growth rate more than 30%, it is not surprising that Coloradans have taken notice.

The future success of the cluster is contingent upon strong leadership on two fronts: internal and political. Internal leadership relates to the leadership of the cluster and the need to have a common voice on key issues and a face to attach with the cluster. Political leadership is essential to ensure that support is provided to meet workforce development needs, investments continue to be made in the state's research facilities and programs, and Colorado maintains a business friendly climate.

Early in 2003, a grassroots effort in nanotechnology began to take shape in Colorado by a consortium of academic, industry, political, economic development, and workforce development leaders. These early champions of the technology believed the best way to achieve Colorado's potential in nanotechnology was through the development of a grassroots initiative. This coalition was successful in generating awareness and interest. While initial efforts lacked clear leadership, the cluster is now united and is speaking with a common voice as a result of a combination of the development of the Colorado Nanotechnology Roadmap, the creation of the Colorado Nanotechnology Alliance (CNA), and the hiring of Debbie Woodward as CNA's executive director.

Brian Lewandowski is a graduate research assistant with the Business Research Division. He can be reached at Brian.Lewandowski@Colorado.EDU.

Nano Roadmap:

RESEARCH AND TECHNOLOGY TRANSFER

John Kreb

While nanotechnology is new to most Coloradans, nanotech research has been conducted at National Institute of Standards and Technology for 25 years and 20 years at the state's major universities. During this period, more than $50 million in federal funding has been awarded to Colorado laboratories and universities.

Looking ahead, Colorado universities and federal laboratories have nanotechnology research capabilities that will make significant contributions to the state's economy in the months ahead. At the federal laboratories, research expertise and facilities for nanotechnology applications are in clean energy, nanomaterial characterization, measurement, and nanotechnology standards.

MORE THAN 95% OF THE FEDERALLY FUNDED RESEARCH AT THE UNIVERSITIES IS CONDUCTED BY THE CU SYSTEM, CSU SYSTEM, AND THE COLORADO SCHOOL OF MINES.

About 70% of the federally funded research that is conducted by universities and companies is performed at the state's major universities. The 30% that is conducted by companies is comparatively high, a testimony to Colorado's entrepreneurial spirit. More than 95% of the federally funded research at the universities is conducted by the CU System, CSU System, and the Colorado School of Mines.

The Engineering Research Center for Extreme Ultraviolet Science and Technology is the only program in the state that has been identified as part of the National Nanotechnology Initiative infrastructure. The program, funded by the National Science Foundation, is a cooperative effort between CU, CSU, the University of California at Berkeley, and Lawrence Livermore Laboratory. Moreover, partnerships have been formed with 18 additional colleges and universities across the country. The collaborative efforts of the program are further emphasized by the extreme ultraviolet industry and education outreach efforts.

Moving forward, it is essential that Colorado maintain investment in its top research universities. The cross-disciplinary nature of nanotechnology requires a strong combination of physics, chemistry, optics, and engineering programs to support it. It is important that future investments in the universities be nonduplicative, since the cost of equipment is prohibitively high. While it is imperative for the current universities to expand their programs and funding, programs at other colleges, universities, and community colleges should be strategically developed.

It is critical that all research institutions together with industry and the federal labs to plan and support a centrally located, common user facility that will provide equipment that is needed by all. Development of this type of specialized center will foster research collaborations, provide a tangible asset to attract research funding and industry partners, and be visible evidence of the state's nanotechnology interests and capabilities. Although Colorado ranks above most nanotechnology peer states in the science and technology index, which is a measure of the state's ability to support a technology-based economy, it has shown comparatively slow growth in recent years. This trend might be reversed by a recent announcement that the University of Colorado recently received a DARPA grant worth $10 million over six years that fosters university/industry collaborations.

A final sign of the potential for the development of nanotechnology in Colorado can be seen in the formation of Phiar, Activ-Dry, ALD Nanosolutions, Kapteyn-Murnane, and Astralux. These companies have spawned out of the federally funded research and commercialization efforts of CU and CSU.

John Kreb is a reseach assistant with the Business Research Division. He can be contacted at John.Kreb@hotmail.com.

Nano Roadmap:

WORKFORCE DEVELOPMENT

Brian Lewandowski

Colorado has long benefited from a well-educated, albeit imported, workforce. The state's natural beauty, recreational access, and 300-plus days of sun are arguably some of the reasons that Colorado draws a highly educated workforce to the state. However, importing a well-trained, highly skilled workforce is not sustainable. Colorado must invest in education and workforce development from pre-kindergarten through the university level in order for the state to maintain a workforce prepared for employment in multidisciplinary technology professions, including nanotechnology, in the twenty-first century.

At first glance, Colorado is considered a well-educated, high-tech state with above-average wages. In fact, in 2003 Colorado had the highest percentage of students in the nation with scores above 1200 on the SAT and above 26 on the SAT. In 2005, Colorado's 8th graders scored above the median in national math and reading exams. The state placed 16th in the percentage of the population with at least a high school diploma in 2004, and 2nd in the percentage of the population with a bachelor's degree. Comparatively, Colorado has a more highly educated workforce than most other states.

However, a closer look at the numbers tells a different story. In 2002, the high school graduation rate of 70.6% placed the state 29th in the country. Examining the number of engineering tech graduates per 1,000 engineering tech occupations, the state ranked 45th, and for engineering graduates per 1,000 engineering occupations, the state ranked 25th, indicating that Colorado companies import a portion of the state's high-technology workforce. In addition, Colorado's shining SAT and ACT scores are actually a representation of merely the best and brightest students taking the exam. More than 80% of eligible students take the exams in the northeast; in Colorado this figure is only 26% (*Rocky Mountain News,* August 30, 2006).

Although Colorado state and local support for higher education general operating expenses has increased by 30.2% since 1991, per capita support (adjusted for inflation) has dropped by 39%, ranking the state 33rd in total support for higher education and 48th in per capita support for higher education in 2005. For the 2003–04 school year, Colorado spending per pupil on K–12 education was 10.5% below the U.S. average, ranking the state 32nd. Colorado allocates $35.74 out of every $1,000 of personal income to K–12 education, placing the state 47th in the country. When K–12 education spending is examined as a percentage of GSP, the state places 45th, with 2.95%. Colorado placed 22nd on spending for pre-kindergarten education per student in 2004, and ranked 26th on per capita federal Head Start program funding in 2003.

In order to increase Colorado's workforce assets internally, the state must boost its support of K–12 science and math programs, introduce teachers to nanotechnology, expose students to nanotechnology careers, promote community college programs for trained technicians, and create university level courses in nanotechnology. In an effort to ensure efficient and rapid commercialization of Colorado research, it is essential to have a nanotechnology workforce that includes well-trained engineers, technicians, educators, and business/legal professionals. It is imperative to have innovative alliances between all levels of education and the private sector. Finally, it is essential to view the training and education of nanotechnology workers as an investment in our state, rather than a cost to taxpayers.

Brian Lewandowski is a graduate research assistant with the Business Research Division. He can be reached at Brian.Lewandowski@Colorado.EDU.

Nano Roadmap:

BUSINESS GROWTH

Brian Lewandowski

Colorado is characterized as a high-tech state because of its strength in electronics, aerospace, homeland security and defense, biomedicine, and energy. Looking at Colorado's high-tech companies as a percentage of total companies in 2002, Colorado ranked second in the nation, with 8.7%. High-tech employment in 2005 represented 173,100 jobs. The state's high-tech gross state product (GSP) topped $33 billion in 2003, or 17.6% of Colorado's GSP. The Milken Institute's Tax Burden Index indicates that Coloradans pay the second-lowest percentage of income nationally, while the institute's Cost of Doing Business Index places Colorado better than average, with costs 6.8% less than the national average. In addition, Colorado ranked second in the Kaufman Institute's 2005 Index of Entrepreneurial Activity. Naturally, then, it would be expected that Colorado has a high per capita income, ranked ninth in 2005, at $37,946. As an enabling technology, nanotechnology has applications in nearly every industry, and Coloradans have a personal stake in not only maintaining the state's high-tech industries, but leveraging new technologies to maintain the state's position as a high-tech leader.

Colorado already has a jump on developing a strong nanotechnology industry, with 75 companies identified as working with the technology. A total of 47% of these are research companies, 42% are manufacturing companies, and 9% are classified as "other." These 75 companies are located in 20 cities and 11 counties along the Front Range and are clustered around Colorado's universities and federal laboratories. A close geographic correlation exists between the location of Colorado nano companies and the location of the aerospace cluster. In 2006, approximately 150–200 full-time and 150–200 part-time employees work in nanotechnology in the business sector. This is obviously a benchmark number and is expected to grow as the cluster and its workforce are nurtured.

In order for nanotechnology to have the pervasive effects of other high-tech industries, state leaders must invest in the nanotechnology infrastructure to support research and commercialization. This effort begins with the fully functional Colorado Nanotechnology Alliance, but spreads much further to include operational tech-transfer offices, shared university facilities, access to university expertise, and exposure to potential investors. It also requires that political leaders continue to make Colorado a business-friendly place for technology-based companies.

Brian Lewandowski is a graduate research assistant with the Business Research Division. He can be reached at Brian.Lewandowski@Colorado.EDU.

Nano Roadmap:

PUBLIC EDUCATION AND SOCIETAL IMPLICATIONS

John Krebs

Economic development is an objective that often clashes with the goal of maintaining the environment, people's lifestyles, and sustainable economic growth. The emerging cluster of nanotechnology is a perfect example of this conflict of interests as it is poised to be a several trillion dollar world market. Growth of the nanotechnology cluster in Colorado has been supported by a strong technology-based economy but for its full potential to be realized, efforts must now be made to meet the unique requirements of the cluster that arise from the health, safety, and ethical concerns associated with the technology.

"IF THIS INDUSTRY IS TO GROW TO ITS PROMISE OF ONE TRILLION DOLLARS BY 2015, THE FEDERAL GOVERNMENT AND INDUSTRY NEED TO PUT AS MUCH ENERGY INTO BUILDING PUBLIC TRUST AS THEY DO INTO DEVELOPING NEW NANO APPLICATIONS."

—DAVID REJESKI

One way to mitigate the problems with the emerging nanotechnology sector is to create a community that is knowledgeable and fully engaged. This includes interaction with researchers, business leaders, and public policy officials in decisions and actions that protect against health and environmental risks while enabling development of economic and social benefits from nanotechnology. A well-informed and vocal public can prevent distrust and rejection of product offerings based on misinformation and fear of the unknown. Public perceptions are greatly influenced by the transparency of research activities and objectives. Product design, material handling, machining concerns, and risks to consumers from product use are of great importance, along with eventual product disposal or waste matters.

"If this industry is to grow to its promise of one trillion dollars by 2015, the federal government and industry need to put as much energy into building public trust as they do into developing new nano applications," according to David Rejeski, director of the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center.

Because there are always unknown risks associated with a new technology, the socially and environmentally responsible development and deployment of nanotechnology is a major concern. Colorado, however, is committed to set a national example in this area in order to avoid such problems. One of the state's major strengths is the Colorado Nanotechnology Alliance (CNA), which has involved a large constituency of industry, academia, government, economic developers, private professionals, legislators, and others in meetings, conferences, and discussions focused on the technology. Organizations such as National Institute of Standards and Technology, the National Science Foundation, and the National Institutes of Health have all been instrumental in providing funding to help research potential risks. Individuals who are involved and knowledgeable about the importance of public perceptions, health and safety, and ethical considerations specific to nanotechnology are active in the Colorado nanotechnology community and have published many works on the subject. Several universities such as the University of Colorado, Regis University, and Colorado State University–Pueblo have conducted research on the societal risks of nanotechnology as well. As a result of the combined efforts of Colorado companies and researchers, the state has the potential to take a leadership position in the socially responsible development of nanotechnology.

John Kreb is a reseach assistant with the Business Research Division. He can be contacted at John.Kreb@hotmail.com.

Call to Action

The potential benefits of nanotechnology are enormous, and the biggest risk is the failure to act—and to act in time. While well ahead in many areas, Colorado is behind other states on some factors critical to building a strong competitive position. Immediate action is required if Colorado is to catch up in time to gain a solid position in the future economy. Colorado has the opportunity, the ability, and the duty to maintain a healthy technology-based economy, a high standard of living, and above average personal income for Colorado citizens. Responsibility for success does not rest solely with the broad-based statewide alliance of organizations committed to supporting nanotechnology, Colorado Nanotechnology Alliance (CNA), but with the concerted efforts of many partners.

Colorado's **elected officials** have the responsibility to initiate and support the policy changes and public financing necessary to ensure that Colorado universities, companies, and citizens share the economic benefits of nanotechnology.

Colorado **universities** share a responsibility to coordinate, communicate, and open their nanotech assets to Colorado industry. In doing so, everyone will benefit from increased research funding, improved laboratories and equipment, more license and royalty income, and a quality educational environment.

Companies of all sizes have a responsibility to their owners, investors, and customers to ensure responsible and ethical nanotechnology development, and an opportunity to work through CNA to communicate their business challenges and needs to educators and policymakers.

As nanotechnology has the potential to create economic growth in nearly every industry and geographic area, **economic development organizations** have a responsibility to promote Colorado's nanotechnology capabilities and resources to help local businesses grow and new companies relocate to the state.

Educators and **workforce development professionals** have a responsibility to work collectively for positive systemic change that focuses on math and science education, interdisciplinary course content, and ethics in business and science ir order to better prepare Colorado youth for high-wage technology jobs.

IMMEDIATE ACTION IS REQUIRED IF COLORADO IS TO CATCH UP IN TIME TO GAIN A SOLID POSITION IN THE FUTURE ECONOMY.

Colorado's highly educated, technology savvy **citizens** have a responsibility to be fully informed and engaged in ensuring the responsible development and deployment of nanotechnology, and in planning and preparing for the social changes it will bring.

CNA is responsible to lead, motivate, educate, and coordinate the actions of many partner organizations for the benefit of all.

This is no small task!

The time to act is now!

COLORADO BUSINESS REVIEW

The *CBR* is a bimonthly publication of the Business Research Division at CU–Boulder. Opinions and conclusions expressed in the *CBR* are those of the authors and are not endorsed by the BRD, the Leeds School of Business faculty, or the officials of CU.

View our Web site: http://leeds.colorado.edu/brd/

Richard L. Wobbekind, editor; Cindy DiPersio, assistant editor; Gary Horvath, technical advisor; Lynn Reed, design.

This report is not produced at taxpayer expense. The University of Colorado at Boulder is an equal opportunity/affirmative action institution.

For information/address change:
Business Research Division
420 UCB, University of Colorado at Boulder
Boulder, CO 80309-0420 • 303-492-8227

Nonprofit Org.
US Postage
PAID
Boulder CO
Permit No. 257

Mark Your Calendars!

FORTY-SECOND ANNUAL

COLORADO BUSINESS ECONOMIC OUTLOOK

December 4, 2006 • Marriott City Center Hotel • 1701 California Street, Denver

Visit our web site for more information
http://leeds.colorado.edu/brd

Sponsored by
Business Research Division • Leeds School of Business • Compass Bank

There is no charge for this event, and no reservations are necessary.