WHAT DOES IT MEAN TO BE A POLYTECHNIC UNIVERSITY IN THE 21st CENTURY?
The Baker Forum was established by the Cal Poly President’s Cabinet* on the occasion of two decades of service to Cal Poly by President Warren J. Baker and his wife, Carly, to further the dialogue on critical public policy issues facing the nation and higher education. The forum gives particular attention to the special social and economic roles and responsibilities of polytechnic and science and technology universities.

The health and prosperity of humanity in the 21st century depend upon our ability to sustain and increase the pace of scientific and technical innovation. Polytechnic and science and technology universities must lead the way in ensuring that these innovations are applied broadly to serve the interests of society and in preparing new generations of innovators and problem-solvers.

The biennial Baker Forum provides an opportunity for polytechnic and science and technology university presidents and industry leaders to come together in an issue-focused, highly interactive setting designed to promote international dialogue, highlight issues of critical importance and stimulate creative responses.

Funding support from the President’s Cabinet, friends of the university and John Wiley & Sons, Inc., is gratefully acknowledged.

*The Cal Poly President’s Cabinet is a senior advisory group of business, industry, government and community leaders.
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With the creation of the Baker Forum in 2002, John Wiley & Sons, Inc., generously established the Wiley Lifetime Achievement Award. This award, presented at the Baker Forum, recognizes extraordinary leadership and lasting contributions in American higher education and public life.

John P. Morgridge, chairman emeritus, Cisco, is the recipient of the 2008 Wiley Lifetime Achievement Award.

Past recipients include: David L. Goodstein, vice provost and professor of physics and applied physics, Cal Tech (2006); William C. Harris, director general, Science Foundation Ireland (2004); and Walter E. Massey, president, Morehouse College (2002).

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he theme of the 2008 Baker Forum, “What Does It Mean To Be a Polytechnic University in the 21st Century?,” was especially timely and relevant, given Cal Poly’s yearlong focus on reviewing and updating the university’s strategic vision, priorities and goals.

Cisco Chairman Emeritus John P. Morgridge’s keynote address, “The Future of Polytechnic Education,” outlined the attributes polytechnic universities should develop in their future graduates, emphasizing the value of applied approaches to learning. Morgridge set his remarks within the context of a rapidly evolving global scientific and technological landscape and a world confronted with great challenges, none more pressing than the effort to build a sustainable future.

Following Morgridge’s talk, forum participants had an opportunity to hear insightful presentations on:

- The importance of developing a diverse, globally attuned science and technology workforce (Charla Kamm Wise, corporate vice president, technology, CEESH, Lockheed Martin Corporation)
- The concept of a new liberal education, striving toward a synthesis of scientific, technological and liberal arts competencies (Richard M. Miller, president, Franklin W. Olin College of Engineering)
- The growing importance to polytechnic universities of industry, university and government partnerships (David J. McLaughlin, professor, electrical and computer engineering, University of Massachusetts; and Mark E. Russell, engineering vice president, Integrated Defense Systems, Raytheon Company)

The forum revealed a rich variety of viewpoints among the industry, government and education leaders in attendance. I believe it is fair to say, however, that there was general agreement that polytechnic universities and their graduates need to play an increasingly central role in helping society address the grand environmental, technological, economic and societal challenges of the new century.

In the wake of the forum, Cal Poly has continued the comprehensive review of its strategic plan. The President’s Cabinet is pleased now to be able to share these proceedings of the 2008 Baker Forum as a resource to Cal Poly and to individuals and groups interested in better understanding the role of the polytechnic university in the 21st century.
John P. Morgridge, chairman emeritus of Cisco, emphasized to the 2008 Baker Forum audience California’s—and America’s—urgent and growing need to educate scientists and engineers to support our high-tech infrastructure. Graduates of Cal Poly and other polytechnic institutions, Morgridge said, must be ready to enter a rapidly evolving global marketplace as the 21st century becomes the “Age of Information,” where competitiveness depends on an innovative workforce with hands-on experience and the ability to work effectively in teams to meet the challenges of a world undergoing accelerating technological change.

In addressing education’s vital role in preparing the United States to compete successfully in the new global tech economy, Morgridge identified five areas for special attention:

- Desired attributes of a polytechnic graduate
- The importance of an applied approach to learning
- Trends in scientific and technological innovation
- The importance of international collaboration
- Building a sustainable future

Morgridge, former president and CEO of San Jose-headquartered Cisco, described California as still residing at America’s technology center.

“Many members of the National Science Foundation and a large group of Nobel laureates are here in California. One of every four U.S. patents is granted in California, one of every five U.S. tech jobs is here, and certainly California is the center for venture capital, gaining nearly half of the total investments made in the country.”

California has an immediate and growing need, Morgridge said, for well-educated high-tech workers to maintain the state’s national and international leadership role in developing the new century’s breakthroughs in processing and communicating information.

“Recent studies have shown that California will need between 20,000 and 24,000 additional engineering graduates over the next 10 years to support its infrastructure across a broad array of engineering pursuits. To stay competitive, the state has to do research, make new discoveries, continue its prominence in agriculture (through cleaner agricultural technology) and develop stronger information technology, nanotechnology and biotech capabilities.”

Cisco and the state’s tech industry presently face a shortage of trained workers—Morgridge told his listeners that only 30 percent of California high school graduates now go on to college and warned that the state’s primary and secondary education system—as well as the nation’s—needs readjustment to interest more students in science and technology careers.
“Each year America’s information technology industry requires 150,000 trained new employees in hardware, software, applications and support. However, our colleges are currently producing 50,000 graduates a year in the tech fields.”

To illustrate the importance of educational preparation for the high-tech workplace, Morgridge presented a profile of Cisco employees:

- Sixty percent have four-year bachelor’s degrees.
- One-third have master’s degrees.
- A limited number have two-year tech degrees.
- Only four percent have only high school diplomas.

Morgridge noted that within colleges and universities the learning process is undergoing remarkable changes and will continue to change in the next 10 years.

“As one of my colleagues recently observed, students now arrive at universities with a ‘bandolier’ of electronic devices—cell phones, pagers, BlackBerrys—and they use these communications technologies not only to dialogue with friends and families around the world but also as a major source of information and, indirectly, as a major source of learning.”

This communications revolution, Morgridge explained, is transforming the ways students absorb, organize, analyze and employ knowledge and information, and will dramatically affect how educational institutions prepare scientists and engineers for research and development in a world shaped by rapid technological advances.

“Learning is going to be hands-on, perhaps through simulation, but certainly with a strong emphasis on applied, experienced-based instruction. Teaching techniques will be interactive, maybe ‘virtual,’ with an emphasis on the collaborative and the global.”

Morgridge highlighted three primary attributes polytechnic graduates will require to succeed in today’s high-tech workplace:

- The ability to observe
- Practical hands-on experience, through university training and industry internships
- A set of principled values

Keen observation skills and practical experience provide the future tech-industry worker with a basic foundation for carrying out the vital technical tasks that will ensure American competitiveness. Morgridge quoted a recent university survey identifying five key strengths graduates need for success and added a sixth skill he believes critical. Modern high-tech workers need to:

- Think like scientists and solve problems
- Work in multidisciplinary and multifunctional teams
- Communicate effectively with a wide spectrum of fellow workers
- Demonstrate depth of knowledge in their fields
- Continually learn new things in a changing environment
- Have an awareness of “diversity” in the broadest sense: cultures, disciplines, and scientific, technological and financial pursuits

Morgridge stressed that within Cisco the premium placed on problem solving extends “across the board,” not only among engineers and software developers, but in sales, service, finance and human resources. He underlined that Cisco’s success in “conceiving, developing and launching new products, procedures, operational methodologies, or sales-force or service-organization structures” relies on employees
able to cross disciplines and functional areas "to work with people who hold a different point of view, have a different life experience and different training.

"Communication skills are especially valuable. Though a tech worker’s punctuation in e-mails might not be as proficient as an English professor would require, employees must have the ability to describe and explain their ideas to others in a clear, organized form in both writing and speaking."

Morgridge insisted that the polytechnic graduate needs not only a sure knowledge of a discipline’s essential scientific principles but also a range of learning that will allow the scientist or engineer to bring flexibility and a well-rounded approach to problems and their solutions.

"A depth of knowledge in the field is fundamental, to be well grounded in whatever the chosen area of expertise. Along with the obvious necessity of 'being deep', there's a needed ability 'to go broad.' That's the real challenge, and the real challenge for teachers and students at Cal Poly and other institutions. At Cisco, the polytechnic graduate's ability or depth of knowledge within a discipline is not our primary concern, but rather the combination of this proficiency with an equally important breadth of knowledge."

This “widens” of knowledge and interests readies the graduate for the evolving nature of the high-tech industry and the competitive global market where new technologies vie for prominence.

"The ability and desire to continue to learn,” Morgridge suggested, is a mandatory talent in the world of high tech and is his addition to the list of “musts” for polytechnic graduates. "This is a fast-changing world and you have to be learning all the time—your learning never reaches a maximum but continues to evolve.”

Tech workers must be flexible, not only in their continued openness to change and new kinds and sources of information, but also in personal relations, in order to function effectively and creatively in a world of increasing diversity.

"Diversity awareness (and I use the word 'diversity' in the broadest sense) is a fundamental requirement. Cisco is a global corporation and has a sensitivity to all of the world's cultures. Diversity awareness involves perception, understanding and a positive appreciation of differences, whether they are cultural or national or involve varied disciplines and areas of scientific and technological research and development. Practical means to increase diversity awareness include apprenticeships and cross-disciplinary and cross-cultural projects and joint efforts with institutions in other countries. Perhaps universities should place greater stress on learning foreign languages or require future graduates to take part in programs that provide them with international experience. Study that increases exposure to the wider world can be an integral part of the polytechnic undergraduate’s preparation for the global high-tech marketplace."

A strong sense of personal ethics, Morgridge underscored, is as important as the other necessary abilities future scientists and engineers must possess.

"In spite of all you’ve read about some of the disastrous things that have happened within business, I think that there is a drive now within many corporations to set very high standards in terms of moral and ethical values. These learned values typically come from our parents but our educational system also has a significant role to play, beginning at the primary and secondary levels and certainly within undergraduate and graduate
institutions. Ethical values need to be taught and learned within all our schools, and it is vital that we set and maintain those standards across the entire range of educational activities.”

Volunteer community enterprises that bring people together to improve the lives of fellow citizens are central in establishing community values and deepening the individual’s moral intelligence.

“Through community involvement we learn who we are and the kinds of standards that we establish for ourselves and others. In the business school at Stanford we conducted a study of high-tech company presidents in the Silicon Valley. We wanted to learn what experiences had set their moral compasses, how they located and kept to their ‘true north,’ especially in difficult situations. We discovered that involvement in the community and concern for its betterment was a determining factor in developing their system of ethical business behavior.”

The “value skills” all workers within the tech industry will require include:

- Personal and professional responsibility
- The sensitivity to treat fellow workers with fairness and respect
- A sense of “fair practices” in finance and entrepreneurship
- A strong work ethic based on the fulfillment of daily tasks
- An awareness of job performance and the willingness to constructively use professional feedback

To illustrate the “real-world” working environment of the contemporary high-tech industry, Morgridge presented a brief overview of Cisco and then sketched a portrait of the ideal Cisco employee.

“When I joined Cisco I was the 39th employee—we now have 62,000 employees around the globe. We are in about 70 countries and have more than 300 offices, with major support centers in Amsterdam, Bangalore, Singapore and Australia. Our operations are one-third in engineering and one-third in sales and service, with the remaining third in all other endeavors within the company.”

In describing the qualities Cisco seeks in its job candidates, Morgridge said, “We certainly look for ‘drive’—this is a 24/7 industry—and all of our employees must have energy and ambition. And we look for character, for people with integrity, intelligence, a positive attitude and, especially, the ability to lead. Almost all Cisco employees, in their work as team or council members, will hold leadership positions. Cisco’s workforce enjoys a large measure of personal flexibility and through stock options participates in the company’s success. The retention rate at Cisco is very high and employee perquisites include online services, which range from ordering medical prescriptions to real-time monitoring of children in our child-care facilities.”

Cisco employees enjoy their work, work hard and are goal-oriented, Morgridge said, and function well in a changing environment that is constantly under review.

“We do a lot of measurement at Cisco and all
of our employees have a once-a-year general review, what is called a ‘360’—everyone who reports to them, everyone on their peer level, their managers and external observers provide direct feedback about strengths and challenges. We look for creativity, the ability to work with other people, efficiency within the organization, and a passion for one’s present position and a desire to rise higher within the company.”

Cisco’s success depends on teamwork within all levels and across all levels of its operation, because launching new products in the global marketplace demands the concerted efforts of all employees, from administrators who set company strategies and goals to scientists and engineers to those working in finance, sales and customer service.

“At Cisco, collaboration is a byword and takes place within working teams and task forces, within functional areas and across functions, and across product lines to discover new solutions. Cisco boards at various levels address in a matrix fashion a wide range of activities so that when we introduce a new product we know that every aspect of the project has been coordinated against a background of satisfying the needs of specific customers.

“Much important work is done within our ‘business councils’—cross-functional teams that analyze and address principal market areas. We have a council that concentrates on sales to service providers, telephone companies and the cable companies. We work across the entire spectrum, creating councils from the various functional areas to provide a total support arrangement for individual marketplaces.

“At the top of our pyramid, operating committees determine overall strategies and assure that we have set proper objectives and are meeting them. In short, Cisco is truly a collaborative institution.”

Constant change, Morgridge emphasized, is the technological, marketing and cultural definition of the high-tech revolution, and Cisco’s strategies are based on the certainty of a changing global tech and business environment that demands constant flexibility, foresight and adjustment.

“In our industry, change is what we have to do to succeed. For example, when a financial crisis in Asia caused many of our competitors to retreat from the Chinese market, Cisco chose to expand its efforts, because we thought that the negative conditions were temporary and offered us a competitive advantage. As the Chinese marketplace recovered, we became a dominant force there. Our strategy in China is just one of many ‘change decisions’ Cisco has made and illustrates the importance of meeting and adjusting to change.”

The need to anticipate and respond to shifting national and global tech-market conditions is mirrored in Cisco’s dynamic internal organization.

“At Cisco our fiscal year ends in July and every summer we reorganize our field sales force. Changes often include the re-division of accounts and market territories and the reassignment of our sales representatives. The willingness of successful sales personnel to venture into new territories and assume new responsibilities and challenges helps nurture a culture within our company that is continuously evolving.”

One recent change in worldwide marketing involved Cisco’s redrawing of the traditional approach to serving market areas.

“Usually global territories are divided by geography, by continents. Instead, we grouped our markets by their immediate technological needs and levels of economic development, so that countries such as Brazil, Russia and South Africa were placed within one sales entity. Their high-tech requirements were similar, and we were able to employ a single strategy comprising
techniques, solutions and financial arrangements that sharpened our marketing focus, producing maximum benefits for Cisco and our clients.”

Again, Morgridge reminded his audience that the ultimate success of Cisco and other American high-tech companies is based on the quality of our colleges and universities, where our future scientists and engineers receive crucial hands-on instruction, and research and development produce advances in technology that generate new industries and new high-tech companies.

“Our universities provide the United States with one of its greatest competitive assets. Universities like Cal Poly that both teach and conduct research provide a unique educational combination not found in Europe or Asia. Particularly within our land-grant and some of our private institutions, we have developed the capability for cutting-edge research alongside the primary mission of progressive, broad-based education. Many important scientific and technological ideas are discovered within our universities, and universities incubate new high-tech companies like Cisco, whose first stirrings took place in 1984 at Stanford—Sandy Lerner was my teaching partner and became one of the future founders of Cisco. Indeed, most of the other leaders in the high-tech field—Yahoo, Google, Network Appliance—had their beginnings on college campuses.”

Morgridge detailed how innovative research at Stanford provided the launching pad for Cisco.

“I joined the company in 1988 and that year we shipped our first multi-protocol router. A router allows for the direction of Internet or network traffic, not by broadcasting as a radio does, but by actually determining addresses by their protocols and sending messages to their correct destinations. That was the breakthrough that allowed the development of mixed environments on the Internet, so that the equipment of various vendors could coexist in a single network.”

The multi-protocol router that identified parts within the wider network provides an analogy for Cisco’s general approach to the technology market.

“At Cisco, our continuing strategy has been to analyze the ‘tech ecosystem’ and the key parts within it—to identify those parts that Cisco does a good job of providing, and the needed parts that Cisco doesn’t presently provide. We then find companies that best produce those parts and try to integrate them into Cisco. Crescendo, our first acquisition, was purchased in 1994 for $100 million and became the foundation of our switching business, which accounts for $6 billion to $8 billion of Cisco’s revenues.”

Cisco’s strategy is based on constant expansion in what Morgridge believes is the beginning of the “Age of Information,” an age in which the means of information communication are undergoing revolutionary change and corporate competitiveness will depend on offering the most advanced technology and service.

“Cisco has introduced what we call ‘Telepresence,’ which is a high-grade video conferencing technology, and acquired WebEx, a technical innovation that allows multiple individuals to work on a single online project from various locations. Though the Age of Information has just begun, we are now perhaps at a turning point as we attempt to craft synergies to join and integrate a range of technological capabilities.”

Future technologies, Morgridge predicted, will combine audio and video and impact everyone on personal, community, social and educational levels as global networks of people, companies and economies arise. Already the Internet enables and encourages partnerships between far-flung cultures at
different stages of economic development and is an excellent engine for micro-targeted fund raising, loans and international projects to aid deserving individuals around the world.

“CIVA [The Centre for Innovation in Voluntary Action] is an online system that lets an individual donor make a specific loan to a small business in Asia or Africa. CIVA was begun about three years ago by a colleague in the business school at Stanford and the program has raised over $15 million in loan projects via the Web. Online, a donor can meet a farmer or a woman who runs a small business and make a specific loan to the individual. The repayment rate is very high and the loans have made a dramatic impact on the profitability of Asian and African farms and businesses. We are becoming a global community—the Web enables you to go almost anywhere in the world. The opportunities the network offers will continue to enhance world communications and become an even more central element of instruction and experience at institutions like Cal Poly.”

The new communications technology, Morgridge said, is transforming the work culture at Cisco.

“The power of the network allows many of our employees to work at home or the office, from distant locales. The Cisco employee who helped me prepare this presentation lives in Honolulu, Hawaii—she is a communications expert for several of our executives. Cisco’s new product, Telepresence, lets members of Cisco’s different boards ‘meet’ regularly in ‘televised space,’ without the time and cost of travel. Already Cisco has built 125 Telepresence centers.”

The electronic transmission of information, procedures and processes fosters a bond of shared experience and social values among Cisco’s global employees.

“This year’s annual Cisco food drive that raised $3 million began on the West Coast in San Jose and expanded across the United States, then to Europe, India and Asia. Pictures and text posted on the Web were seen by our employees worldwide, who wanted to be a part of a growing humanitarian gesture. Within Cisco, a company culture is generated electronically—every Monday our global sales force forecasts the amount of business that will be completed within the next five days. Human resource procedures and processes are also handled online. For example, at Cisco employees book their business travel online and the travel request automatically goes through our different screening procedures to ensure compliance with company policy. In addition, skill development tools and employee assessment guidelines and techniques are online so that the Cisco ‘culture’ is the same in China as it is in San Jose, California.”

Morgridge stressed that the global free flow of ideas will change the incubation of new products and processes and put a new emphasis on partnerships and collaborations.

“We have a hands-on, innovative learning process—the I-Zone Wiki—that’s available to the entire company and provides a place for Cisco personnel to exchange ideas and build teams around those ideas. Recently Procter & Gamble announced that it has set as a goal that 50 percent of its product ideas will come from external partners. That’s a practical, realistic acknowledgment that we’re operating in an Internet world, where online information moves freely among people from all over...
the globe and ideas can be evaluated and implemented by employees working in teams. Our employees go online to gather industry information, enter account information, and communicate with clients and deliver services around the world.”

Technological advances in communications are especially evident in the way Cisco keeps its 62,000 employees aware of the company’s day-to-day operations, while new innovations offer amazing possibilities that rival those of “Star Trek” and other depictions of future worlds.

“John Chambers, Cisco’s CEO, speaks to every Cisco employee on an almost daily basis through the network. He is seen ‘live’ in a variety of venues—addressing analysts or business leaders, speaking to government officials or launching our campus in Bangalore. At the campus opening we demonstrated our new ‘virtualization’ technology—we actually ‘beamed’ three-dimensional live images of two people in the United States to India. John Chambers stood on stage with his colleagues in America as together they delivered the presentation. It was an amazing sight and the kind of innovation that’s coming.”

This globalization of business, produced by the worldwide access to information and the speed of modern transportation, has increased social awareness across the planet and especially at the corporate level—from the leaders of corporations understand that their businesses will be measured socially by the greater world, in terms of educational and humanitarian support and concern for our physical environment.

“At Cisco, we do a lot of partnering. We have an economic development partnership in Lebanon where we are working with a number of other companies. And Cisco has a green program under way. Perhaps the most significant part of our environmental policy is inspiring our employees to take action, as they’ve done in limiting the use of aluminum and plastic beverage containers.”

Cisco’s sense of social responsibility can especially be seen in its educational efforts, Morgridge said.

“Our Cisco Networking Academies, which teach students to design, install and maintain networks, were perhaps the first global use of technology to deliver educational training. We provide the 18-course curriculum, the network and the online instructor training. Classes are conducted in what we call a ‘mixed environment’—the instructor works with students who all have their own PCs that provide texts, examples and simulations. The academies were begun 10 years ago and in California there are approximately 150 institutions that use this program, many of them high schools and two-year community colleges. Cisco Networking Academies operate in 160 countries, have taught 2 million students and currently have an enrollment of over 600,000 students. We’ve found that over 90 percent of our students later use the skills they’ve learned and 80 percent go on to higher education.”

At Cisco, Morgridge believes, social awareness means providing solutions as well as technology.

“After Hurricane Katrina, Cisco made a commitment of $40 million over a five-year period to help reenergize and modernize 40 schools in Louisiana and Mississippi. We had four goals: upgrading all the technology, training teachers, helping with the development or purchase of applications, and making each school an outreach center for that community. For Cisco, and I think for many people in hurricane-damaged areas, it has been a very satisfying program.”

In closing, Morgridge thanked the Baker
Forum audience for the opportunity to share his experiences in California’s high-tech industry, to describe the challenges and rewards of the ongoing technology revolution, and to offer his sense of future directions as our world culture continues its transition to the Age of Information.

**DISCUSSION**

After the keynote presentation, Stephen Ciesinski, CEO of Lazlo Systems and chairman of the Cal Poly President’s Cabinet, invited members of the audience to pose questions to Morgridge.

**Question:** “In the future, how well will America compete in the global marketplace?”

**Morgridge:** “Well, we know that other countries have been very competitive. Across the globe educational institutions are racing to copy the American model. The United States has done very well—in the worldwide market perhaps better than any other nation—but the world is changing and competition will become greater. A major transition in technology is taking place and our abilities to adapt swiftly will be challenged. Fortunately, the majority of the world’s new technology is presently developed in the United States. However, we should understand that when Africa builds its communications systems they will be state-of-the-art and have little immediate need for additions. And the fact that China and a number of other countries have completely bypassed fixed-line systems presents American high-tech companies with a growing challenge.”

**Question:** “What is the future of intellectual property?”

**Morgridge:** “There is currently a heated debate in Congress over a bill that if passed would alter patent law and—according to some of the major universities and pharmaceutical companies—might weaken patents. I think that patents are going to undergo some change, either formally through law or in some other way. The government has been somewhat casual in permitting the patenting of processes that are not necessarily simple but obvious. I think that those patents are going to be challenged and that patents and patent applications will be more carefully scrutinized. I hope the government will spend more money to better handle patent applications, because there’s presently a large backlog and I think that in many cases patent requests receive very little time for review. I know that Cisco would like to see a change in the way applications are handled.”

**Question:** “Could you address the fact that the United States is lagging behind other countries in providing its citizens with high-speed Internet access?”

**Morgridge:** “With the exception of rural electrification and attempts at providing our citizens with equal services, our government has not historically undertaken the kinds of national projects initiated in some other countries. In the United States it has been difficult to build momentum for high-speed access, but I believe this important infrastructure will become more available because American business and our economy will demand it. I do think that new technologies such as Cisco’s Telepresence, which has very high bandwidth requirements, will encourage the spread of high-speed access.”

**Question:** “You underlined in your speech...”
the strategic problem that California and the nation face in interesting our high school students in careers in science and engineering. A shortage of trained professionals presents a problem for all of our technology industries. What can a major high-tech company like Cisco do to address a national shortage of scientists and engineers if our government is unable to provide solutions?

Morgridge: “In the past we have tried to offset insufficient numbers of American high-tech workers by attracting scientists and engineers from other countries, but recently that practice has come under review. Companies in need of skilled workers are in a very difficult situation. As I pointed out in my presentation, the information technology industry requires 150,000 trained new employees every year, but our colleges are graduating only 50,000 students a year in tech fields. This shortfall of 100,000 employees is going to be satisfied in one way or another. Either we will reenergize our American student population to fill those positions or companies will look elsewhere, certainly to India and China. One of the major reasons Cisco developed its networking academies was to begin training future tech workers, to help alleviate what has historically been a shortage of high-tech employees. To interest sufficient numbers of students in science and engineering we have to begin in the high schools.”

Question: “As a student who is going to be interning at Cisco this summer, I know that Cisco is interested in expanding its consumer market. Could you describe some of the new products or technologies that we may be seeing soon?”

Morgridge: “We are presently producing the Linksys Wireless Access Point Setup and will be expanding in that market. We want a stronger presence among small businesses that employ as few as three or four people. Small businesses need routers, iPhones, perhaps a video conferencing capability. We are certainly going to do a lot of development to serve those Cisco customers.”

Question: “Over the last 20 years a sea change has been under way in our understanding of how human beings learn and remember. Could you comment on some of these advances in research and how they affect teaching techniques?”

Morgridge: “I was in Madison, Wisconsin, yesterday and attended a seminar on the clash of cultures between the humanities and arts and the sciences. There is currently no certain understanding of how the brain and mind work, or how they work together. A description of how the brain functions was part of the seminar. Information input stimulates electrical impulses and the movement of the electronic charge across the synapses, triggering both memory and the process of applying memory to use new information. In the next decade I think we will know a lot more about how the brain learns and how it uses existent memory in handling new information. I will say that none of Cisco’s online training sessions lasts longer than 15 minutes. Cisco has learned a lot about the electronic transfer of knowledge and we’ve found that 15 minutes is the maximum time for optimum integration and retention of information.”
In the occasion of the 2008 Baker Forum, Cal Poly is pleased to join with John Wiley & Sons, Inc., to honor John P. Morgridge's outstanding contributions to technology innovation, educational access and academic excellence.

In 2002, John Wiley & Sons, Inc., generously established the Wiley Lifetime Achievement Award to recognize national leaders whose work exemplifies extraordinary leadership and lasting contributions in American higher education and public life.

In the two decades John Morgridge has served at Cisco—as president and CEO, chairman, and now chairman emeritus—the company has become the worldwide leader in networking for the Internet. Under Morgridge's leadership, Cisco has emerged at the forefront of a global technological revolution that has resulted in an unparalleled blossoming of communication, interaction and collaboration among the world's diverse cultures and societies.

At Cisco, Morgridge helped create a culture of innovation, empowerment, economic prudence, and social awareness and investment. As chairman emeritus, he continues to champion a range of educational and corporate citizenship initiatives and remains a guiding force in Cisco's long-term commitment to addressing basic human needs, increasing access to education and furthering development of a more humane world.

Morgridge speaks to audiences worldwide, sharing his insights on entrepreneurialism, strategic management and principled leadership, and philanthropy as he presents new and important ways that education and technology can fuel global economic development.

With his wife, Tashia, Morgridge actively supports a range of education, conservation and human services initiatives.
Stephen Ciesinski, chairman of the Cal Poly President’s Cabinet, introduced the Baker Forum sessions’ three speakers and commentators and their topics addressing the forum’s 2008 theme, “What Does It Mean To Be a Polytechnic University in the 21st Century?”:

- “Developing a Diverse Science and Engineering Workforce with a Global Perspective” – Charla Kamm Wise, corporate vice president, technology, CEESH, Lockheed Martin Corporation
  
  With comments from Gary L. Bloom, former chairman and CEO, VERITAS Software Corporation

  
  With comments from Susan Hackwood, executive director, California Council on Science and Technology

- “Industry, University and Government Partnerships” – David J. McLaughlin, professor, electrical and computer engineering, University of Massachusetts; and Mark E. Russell, engineering vice president, integrated defense systems, Raytheon Company
  
  With comments from Keith Fox, CEO, Keith and Pamela Fox Family Foundation; investor, alternative energy
DEVELOPING A DIVERSE SCIENCE AND ENGINEERING WORKFORCE WITH A GLOBAL PERSPECTIVE

Charla Kamm Wise
Corporate Vice President Technology, CEESH – Lockheed Martin Corporation

Comments by Gary L. Bloom
Former Chairman and CEO, VERITAS Software Corporation

Stephen Ciesinski introduced Charla Kamm Wise by saying, “Charla Wise has nearly three decades of experience in the global aerospace industry. A pioneering woman engineer in a traditionally male-dominated industry, she has led major programs and functional departments and held corporate leadership positions. She has also played an active role in national policy conversations concerning diversity, including The National Academy of Engineering’s forum on engineering diversity.”

As background for Wise’s presentation, Ciesinski offered three brief observations about diversity in America and the world:

• “With the rapidly changing demographic profile of our nation, development of a more diverse science and engineering workforce is a key imperative for the United States in the 21st century.
• “Many of the 21st century’s challenges and opportunities are global in character and scope: Concerns about climate change, resource scarcity, population growth, economic change and development, and scientific and technological innovation are shared by every nation and have the potential to foster both collaboration and conflict.
• “The diversity of America’s population is an advantage in pursuing opportunities for global collaboration and partnership.”

Wise began her address by responding to Ciesinski’s introductory remarks, stating that, as a polytechnic university, Cal Poly “has the obligation to prepare graduates from diverse backgrounds to function successfully in a complex global environment” and suggesting that this important institutional responsibility would require changes in the “formal and informal preparation and experience of students who will become the nation’s future scientists and engineers.”

The American workforce is aging, Wise told her audience, and in coming years there will be a shortfall in American workers, especially in scientific and engineering sectors, which presents the United States with both a challenge and an opportunity.

“Census information tells us that our country has 304 million citizens and a current workforce of almost 154 million, which according to the Bureau of Labor and Statistics will grow by approximately 15 million workers in the next decade. At the same time, an aging baby boomer generation—people born between 1946 and 1964—means America’s workforce is growing older, a trend that has increased over the last century and will continue in the 21st. In 1900, 13 percent of the population was age 50 or older. By 2000 that number had grown to
27 percent, and if we project the rising curve to 2020 we find that approximately 35 percent of the population will be over 50 years old. Not all baby boomers eligible for retirement will retire, but the aging of their generation does mean that, in the future, a brain drain will affect the U.S. workforce.”

In the United States, Wise emphasized, enrollment and graduation in science and engineering programs must increase to meet the nation’s growing need for trained professionals. However, the United States is presently falling behind other countries in the number of engineers it graduates. The rising demand for engineers and scientists will require that our nation produce more total graduates in engineering and scientific fields.

Wise warned that our national need for more technically trained professionals coincides with worldwide challenges and transformations that will require scientific and technical responses and solutions. Among the challenges she highlighted were climate change, shortages in resources such as food and fuel, and a human population explosion. She stressed that changing global marketplaces, increased competition, and our growing concerns for national security will continue to present new and unprecedented problems requiring the skills and expertise of a large, diverse, well-educated American workforce.

“America must develop a new face and a new paradigm,” Wise said, “a challenging effort that I like to call an opportunity. John F. Kennedy once noted that the Chinese written word for ‘crisis’ is composed of two characters, one representing ‘danger’ and the other ‘opportunity.’ It is possible that we may not have a severe, impending workforce crisis in science and engineering, but I would rather err on the side of preparation to make sure we have the necessary graduates and technical expertise to ensure a promising future for our country.

“The National Center for Public Policy and Higher Education finds that the U.S. workforce is becoming more diverse, that our country’s increase in population is occurring most swiftly among Americans who belong to racial and ethnic minorities. Unfortunately, the level of formal education among our citizens in these growing demographic groups presently lags behind that of other Americans. The National Center’s policy alert summarized succinctly our looming problem by noting, ‘If current educational gaps remain, there will likely be a substantial increase in the percentage of the workforce with less than a high school diploma, and declines in the higher levels of education completed.’

“Substantial increases in those segments of America’s young population with the lowest level of education—combined with the coming retirement of the baby boomers, who make up the most highly educated generation in U.S. history—are projected to result in a decline in the U.S. workforce’s average education level over the next two decades, unless our individual states begin to do a better job of improving the education of all racial and ethnic groups.”

Wise also indicated that gender issues need to be addressed in scientific and technical areas. “In the United States women earn approximately half of the science degrees that are granted each year, but over half of these graduates are in the social or behavioral sciences. Fewer than 10 percent of American engineering graduates are women, although I understand that at Cal Poly women make up approximately 14 percent of engineering students.”

Wise emphasized the need for dramatic readjustments in our educational priorities if we are to squarely face both the challenges and the opportunities that confront our nation. Providing all American students...
with an excellent K-12 education that stresses the importance of science and math—and the attractiveness of careers in science and technology for both men and women—will be crucial, Wise said, if the United States is to have sufficient numbers of 21st-century scientists and engineers and remain competitive. In an increasingly global marketplace, America's future will depend on the education of its younger citizens.

The 21st century, Wise noted, presents Americans with a new global landscape created by a number of factors: computer technology and the quickly evolving Internet; more open national borders and easier and cheaper transportation; lower wages in other countries that have led to the outsourcing of jobs and changes in the ways Americans do business; and the growing worldwide understanding that an increase in knowledge translates to an increase in economic power. Globalization will challenge Americans' ability to effectively communicate with the world, to use foreign languages and to understand other cultures as we compete on a global level and confront new issues concerning proprietary information and national security.

The advantages of globalization, Wise added, are also considerable.

“We have global collaboration and new partnerships, and increased innovation because of new ideas, which means increased opportunity. We can work around the clock now. Engineers in the United States can work one shift and engineers on the other side of the world can work another. People have increasingly started setting their own work hours, and with computers they can work from home or almost any location.”

These new developments, made possible by technological breakthroughs, will continue to change and shape our world, Wise believes.

“What is my vision for 2020? Our college students have grown up with computers, the Internet and international communication. Interaction among industries and businesses will be worldwide and people will be telecommuting, working from home, able to go to their computers at any time and communicate with anyone, anywhere, on any subject that needs to be addressed. Outsourcing will continue, because competition demands lower prices for goods. We will have more mergers, more consultants, more contractors. And I believe we will be seeking out our educated retirees to tap their knowledge and experience, because once the brain drain begins we will need many of them to return to work and many of them will want to work part time. And finally, we'll have an increase in women in the workplace and many more highly educated professionals from minority racial and ethnic groups in our workforce.”

Wise outlined four areas that deserve our special attention if an increasingly diverse America is to compete successfully in the international marketplace:

• Developing K-12 outreach
• Providing the right culture in our schools
• Educating engineers and scientists
• Preparing a global technical workforce

“First, we must ensure that our pipeline of future scientists and engineers begins in kindergarten and reaches through high school to the doors of our universities.”

Charla Kamm Wise
‘adopting’ schools to guarantee the quality of instruction.

“Second, we must ask ourselves if we are creating the right campus culture for our students. Do all of our students feel comfortable and welcome when they first enter their classrooms and when they interact with teachers and other students? Diversity education is our first step, although too many of us confuse diversity training with existing affirmative action or equal employment opportunity programs.

Understanding our American diversity means recognizing that we are all from different backgrounds and that all of us have a place at the same table. Every girl and boy from every race and ethnicity who walks into a classroom should feel at home and never feel alienated. All students should be able to develop and express their talents to the best of their abilities, and share the special knowledge their individual backgrounds and experiences have given them. We need to honor and value our differences and assure our students that each person is part of a team that is seeking solutions to America’s challenges.

“Third, we must be certain that we are offering our students the correct curriculum. I disagree with some proposals that urge that we dispense with some of our basic courses and replace them with more specialized training. We need to construct a strong and wide educational foundation. This can be accomplished if we add an additional year to engineering education. The extra year would allow an engineering education grounded in the basics, while permitting us to expand the horizons to new technologies and practices. We need to acquaint our students with the new sciences, to introduce our next generation of engineers to an exciting and changing world of science that includes biomedicine, nanotechnology, and new energy and environmental technologies and fields of study.

“Fourth, we must understand that broadening our students’ educational perspectives also includes teaching the global skills required in the 21st-century workplace. The modern worker is no longer dealing only with other people in an office but instead is interacting with people around the world. We need to encourage student exchanges between nations and international studies, and instruct students in global communication and in business traditions and practices in different countries. We all need to develop a global sensitivity, an expanded sense of social correctness and etiquette as we both acknowledge and respect the differences among the world’s cultures. Finally, Americans need to learn other languages, so that we can communicate clearly with our partners and customers in the global economy.

“I believe that the four areas I have highlighted for your consideration also reflect the central challenges that confront Cal Poly and other polytechnic universities. I believe that the future is in your hands, and that our American diversity gives us a special advantage in developing a new global perspective that will be the foundation of America’s success in science and technology.”

Stephen Ciesinski thanked Charla Wise for her presentation and introduced Gary Bloom, inviting him to comment on America’s need for a diverse science and technology workforce.

Bloom began with a warning that failure to educate more future scientists and engineers from all racial and ethnic groups presents California and the United States with a serious, ongoing “risk factor.” He suggested that the workforce shortfall has reached a
“crisis level.”

“Current studies suggest that only 50 percent of the scientists and engineers California’s high-tech industries need come from within California,” Bloom observed. “Many indicators show that the present worker shortage is severe and will become more severe in the future.”

Increasingly, Bloom explained, American industry has had to look to other countries for trained workers.

“Oracle [Corporation] spent nearly $5.3 million in 2007 to lobby our government for help in increasing the numbers of tech workers. Now, to be clear, Oracle wasn’t lobbying Congress to pass legislation that would train more Americans for high-tech jobs. Oracle was asking that the number of H-1B visa quotas be raised, so that more foreign engineers and scientists could enter the United States to fill the shortfall in our high-tech workforce.

“When Bill Gates testified before the House of Representatives’ Committee on Science and Technology, he said, ‘Today our university computer science and engineering programs include large numbers of foreign students. In fact, the Science and Engineering Indicators report showed that 59 percent of doctoral degrees and 43 percent of all higher education degrees in engineering and computer science are awarded to temporary residents.’

“Cal Poly’s President Baker, testifying before the U.S. House Education and Labor Sub-Committee on Higher Education, reported, ‘In the 1990s the number of California baccalaureate degrees in mathematics and engineering experienced a 13 percent decline.’ And in her presentation, Charla Wise has focused on demographic statistics that show educational trends, especially among America’s racial and ethnic minorities, that are troubling and demand dramatic attention.”

California’s and the nation’s present economic weakness, heightened worldwide competition, and pressing global problems that include fuel and energy shortages as well as the warming of the planet, require innovative solutions that depend on increasing numbers of Californians graduating in science and engineering and joining the high-tech workforce, Bloom said.

“At this point, even Silicon Valley—with its historical concentration of innovative talent—is at risk because of the shortage of California residents educated in technology fields. We are increasingly dependent on foreign scientists and engineers and graduates from out-of-state universities and institutions. Many people believe Silicon Valley is seeking H-1B visa increases in order to lower labor costs. In fact, we are searching for highly trained technology workers.”

To underline the severity of the workforce problem, Bloom quoted from another portion of Bill Gates’ testimony before Congress:

“I know we all want the U.S. to continue to be the world center for innovation, but our position is at risk,” Gates said. “There are many reasons for this but two stand out. First, U.S. companies face a severe shortfall of scientists and engineers with expertise to develop the next generation of breakthroughs. Second, we don’t invest enough as a nation in the basic research needed to drive long-term innovation. If we don’t reverse these trends, our competitive advantage will erode.”

Bloom insisted that our nation’s difficulties in interesting sufficient numbers of students in science and engineering careers begin in our public schools, before students ever reach the university.

*Student interest in STEM [Science, Technology, Engineering and
Mathematics-related careers drop off to critically low levels by the end of middle school and declines drastically by the end of high school. Once again, let me quote from Bill Gates’ congressional testimony, which I find fascinating and encourage you to read:

“Graduation rates for our high school students and their level of achievement in math and science rank at the bottom among industrialized nations. Thirty percent of all ninth-graders and nearly half of African-American and Hispanic-American ninth-graders do not graduate on time. Fewer than 40 percent of high school students graduate ready to attend college.”

The solution for increasing the STEM pipeline, Bloom said, obviously starts with the American education system.

“Recent studies suggest that California alone will require 33,000 new science and math teachers over the next 10 years. The Business Higher Education Forum suggests that nationwide we will need 300,000 new science and math instructors by 2015. Perhaps I am preaching to the converted on this topic, but I believe our education system is truly in crisis.”

Cal Poly is in a unique position, Bloom said, to field programs that train future teachers in the most effective methods for delivering first-rate STEM education to California’s K-12 students.

“Cal Poly needs to continue to both focus and expand its programs to support teacher education. Our very successful programs need to be increased in scale, to help solve a very large statewide problem.”

In concluding, Bloom told his audience that Cal Poly graduates in all engineering-related fields should be “well-rounded technologists, innovators and business people. A technical education alone will not allow our graduates to solve the challenges that both California and the nation face. We’re fortunate that Cal Poly promotes a multi-faceted approach. Our hands-on, learn-by-doing philosophy—as exemplified by the project-based initiatives at the Bonderson Project Center, by our undergraduates’ senior projects that demonstrate the skills they have acquired, and by Cal Poly’s focus on an integration of liberal arts, science, math and engineering—is vital in developing the versatile science and engineering innovators of the future.”

Ciesinski thanked Bloom for his response to Wise’s presentation and asked the forum audience for their insights, suggesting that the discussion address Wise’s four focus areas—creating a K-12 pipeline for future scientists and engineers, ensuring a welcoming culture within our public schools, providing the right curriculum for science and engineering students, and developing a global perspective.

DISCUSSION

Warren J. Baker: “I would like to thank Charla Wise and Gary Bloom for highlighting the central issues, and especially for emphasizing the importance of valuing the different backgrounds and experiences of the students who enter our classrooms and laboratories. We need to continue to create learning environments that will attract, welcome and engage more students in science and engineering.

“Jaime Oaxaca has mentioned the need for a systemic approach that encourages families to instill the importance of education in their children. And Bill Swanson, working with his team at Raytheon, has noted, ‘The STEM pipeline issue really looks like a systems problem.’ Bill is absolutely right and Raytheon has put a lot of resources into developing a new way of looking at this problem from a systems perspective.
“One of the critical elements that is part of the larger ‘systems problem’ is our K-12 educational system and its teachers. In discussing ways to improve K-12 education, I would point to our success at Cal Poly and our understanding that Cal Poly can’t exist in isolation from the greater scientific and business communities; that we can’t have a curriculum based on hands-on projects and a learn-by-doing philosophy without having strong partnerships with successful entities in the world outside the university.

“I think that we need to take a similar approach in improving our K-12 system—by improving the connections between our science and math teachers and the scientific community. On a very small scale, some collaboration has taken place in California. The important point is that teachers who are involved outside the K-12 system, who have served internships in industry or national labs, are 40 percent more likely to remain in teaching than teachers without professional experience outside our schools. The California Council on Science and Technology’s critical path analysis of the science and mathematics teacher workforce in California showed that in addition to salary considerations, one of the factors that deterred university science and math majors from entering teaching was their belief that the K-12 system would isolate them intellectually and professionally from the greater scientific community.

“As a nation and as a state, we have to engage more of our society in making teachers successful. And the demographics indicate where the effort has to be targeted. Students from the fastest-growing portions of our population go to schools that have the least-prepared teachers. The present situation has to change—as a high priority, we must focus on teachers and the support of teachers in the classroom. We need to get rid of dry textbooks and, beginning at the preschool level, introduce our students to inquiry-based learning and hands-on opportunities to experience the thrill of science. It is important that they begin to think scientifically, whether or not they ultimately decide to become scientists or engineers. And we are working in this direction at Cal Poly.

“To recruit and maintain sufficient numbers of first-rate K-12 teachers, we need to identify aspiring teachers among our university juniors and seniors majoring in science and math and involve them in lab internships that continue into their early years of teaching, so that learning communities develop within our public schools. Charla Wise’s observation that colleges and industries should ‘adopt’ a school is especially relevant. For example, the Lawrence Livermore and Lawrence Berkeley laboratories, the Sandia National Laboratories, and Raytheon and Hewlett-Packard companies are in a privileged position to aid K-12 education—they already have programs in the schools near their labs.

“The increased involvement of the scientific community could result in a more formal process of educating and inspiring our teachers and their students. For a moment, imagine that you are in the fourth grade and on the nightly television news you see an exciting segment about the Jet Propulsion Laboratory. The next day at school you mention the TV story to your teacher and she says, ‘I’m one of the engineers on that project—I worked on it this summer and I’m going to work on it again next summer.’ You suddenly realize that your classroom teacher is involved in the greater scientific world and its endeavors, and that she is knowledgeable about the opportunities offered by a career in engineering or science.

“I do not believe the K-12 system on its own can solve the problem of attracting sufficient numbers of students to science and engineering careers and preparing them for university study. Our schools need significant help because the resources
necessary to assist K-12 teachers are outside the system—in the corporations, the laboratories and the universities. From our discussions with representatives of the K-12 system—and from the relevant data that we have collected—I believe a consensus exists that our schools must have substantial support from the scientific and engineering communities, which in turn will benefit from robust numbers of science and mathematics students planning careers in science and technology fields.

Gary Bloom: “I think that educators at all levels and in all disciplines need to have hands-on experience in the subjects that they teach, that the importance of ongoing professional involvement outside the classroom is not unique to science and math instruction. I do a lot of volunteer rescue and medical work and recently I spoke with one of the fire chiefs in Monterey County, who was pursuing a master’s degree. He said, ‘My courses are really terrific, because all of the instructors come from backgrounds like mine. They come from business and have done “hands-on” work.’

“The notion that that our educators need to have practical experience is especially true for teachers in the STEM fields. The more that we can bring outside science and business experience into the classroom, the more likely it is that students will view their education as an important and exciting time in their lives, rather than as a kind of sentence. School has become boring to kids. And the reason students are bored is that too many of them feel that their coursework doesn’t relate to anything in the real world. We need to change that perception across our entire educational system, and certainly within STEM instruction, where student apathy has been more dramatic because of the existing nature of the classroom work.”

Charla Wise: “Internships for STEM teachers are important because instructors who can talk about professional work that they are doing outside the classroom can make a real difference in the lives of their students. Students know what a doctor is, they ‘experience’ a doctor, and they have some knowledge of what lawyers do, but they don’t often encounter engineers or understand the work of an engineer. To build enthusiasm among younger students for careers in technical areas, we need to make science and math requirements not punishments but interesting and necessary steps toward exciting, high-paying jobs. We’ve got to begin to instill in our young students the idea that engineering offers attractive career opportunities and enjoyable work. Everything depends on our teachers.

“In preparing my presentation to this forum, I read a study that found that one of the major influences on students who achieve university degrees is the role of the mother. The mother’s level of education was an important factor, along with the involvement of parents in their children’s schools, and the educational advantages of two-parent as opposed to single-parent households. Obviously, early, positive parental interest in education plays a crucial part in the success of our students.”

Jaime Oaxaca: “Stressing the importance of education to their children can be especially hard for parents who are recent immigrants. Many parents are going through difficult economic transitions, from earning low wages to seeking higher wages so that they can afford a car or start to think about buying a home. Most of their energy is taken up in economically improving their basic living situation, which in many cases may take more than a generation to achieve. Their children are vulnerable to negative peer pressures, and improving the public education of new immigrants has not been a priority of many of our politicians. The situation calls for knowledgeable people of good will to involve themselves in creating a much better educational environment.”
**Bloom:** “I think that politicians are interested in the education of new immigrants—but I think politicians are mystified about how to create effective schools that solve the problems the children of immigrants face. I do agree that more emphasis has to be placed on the importance of parents’ involvement in their children’s education.”

**Paul McEnroe:** “My wife teaches in a small, K-8 school in which more than half of the students are Hispanic-Americans. Almost all of their parents are agricultural workers. When she began at the school she found that few of the parents came to parent-teacher meetings and that parents were not making sure that their children did their homework—and then she realized that the parents spoke no English. For a time my wife set up a school for parents on a nearby farm, where after work parents could meet and learn together, and the attendance was very good. As the parents learned English, their children’s grades greatly improved. Ironically, the farm school ended when parents began to take courses at the local junior college. The farm school was very successful, but I don’t how you would motivate other teachers to become involved in similar programs.”

**Susan Hackwood:** “The teaching profession is in true crisis. We hear about the various crises in the educational system but where positive changes can occur is with teachers, who are next in importance to parents in a child’s education. All of the K-12 years—especially elementary school—are very important. However, the school system is incapable of making the necessary major changes that are needed for it to function. Teaching is the only profession that I know of that doesn’t respond to the economic law of supply and demand. In their careers teachers progress through a series of set salary levels—teachers can’t be rewarded or fired and we have to hope that teachers will do a good job. Many teachers are fabulous, motivated and dedicated, but others aren’t. I don’t believe that our political leaders are going to change the school system. Democrats will blame the Republicans for not raising taxes. Republicans will blame Democrats and their support from the teachers’ unions. The governor blames the legislature and the legislature blames the governor. Who can actually go into the schools and make some substantive changes? I believe that industry and the laboratories, because they are the final ‘customers’ for well-educated students, have the ability to circumvent the political confusion that is currently resulting in mismanagement of the system. It is critical that corporations and other institutions adopt schools, and that teachers are placed in laboratories and industry. The most important factor, I believe, is the voice of industry demanding change.”

**Bloom:** “I completely concur that industry and laboratories have an important role in improving the educational system. Government is not going to solve the education problem. I recently worked for a wing of a federal agency—after years of work in an industry-based corporation, I was amazed by the level of government inefficiency and bureaucracy. I believe that to succeed our schools will need private, industry-based support, and the opening of industry laboratories to our teachers, as well as help from the general society outside the educational system.”

**Wise:** “Our schools require the help of an across-the-board partnership that includes the university. Earlier, in my presentation, I mentioned the Chinese word for ‘crisis.’ As I prepared my speech I realized that I had ‘crisis’ written at the top of my charts and I changed the word to ‘challenge and opportunity,’ to make my emphasis more positive. I think we’re all convinced that the educational system is in crisis. The problem is that we’ve talked about it and have been
talking about it for a long time. Now we have to decide how to take action.”

**Robert Robbins:** “I really believe that the universities can play a huge part in improving our schools. Jim Barksdale gave $100 million to the University of Mississippi years ago—at the time, it was the largest gift to any public institution and it set up a program to teach teachers to teach better. One step universities and their schools of education can take to become more competitive in attracting philanthropic support is to develop effective programs and promote them.

“A second step the universities might consider is to begin outreach to our communities to encourage support for our schools. Mobilizing people means going to where they are. We’ve got to go to the churches, to the gathering places, to the barber and beauty shops. Universities know how to educate and they know how to reach teachers. Is there a way that the university could be the broker in a novel program set up and funded through industry, to disseminate information and increase public concern for our schools? I think the idea of adopting a school is excellent, especially if the support were efficiently structured through university programs.”

**Bloom:** “Your ideas are interesting ones. I think the challenge for gaining support for new programs becomes one of scale. The Gates Foundation, for example, has made it clear that it wants to solve problems on a large scale, and has emphasized that it is seeking wide-reaching solutions. To attract sufficient funding, proposals require a magnitude of scale.”

**Bruno Giberti:** “I acknowledge the frustration of dealing with government, but I want to disagree a bit with the notion that we can solve the public education problem through private efforts. We need to remember that our present pipeline of scientists and engineers is largely publicly supported, and that raising the level of American education was achieved by some very significant public efforts by both the state and the federal government. The GI Bill and California’s public university system are obvious examples. I have to believe that any real solution of the education crisis will come from making education a topic of public conversation, and in reaching some larger compact with the citizens of California.

“I’ve been involved for a few years in strategic planning in the California State University system, and all of the alarming facts and figures concerning public education are well known by those of us studying the problem. At the same time, there seems to be a difficulty in arriving at a sense of urgency, both within the CSU system and throughout California. The crisis in education has not seized political or public conversation and I don’t see a solution coming until we begin to consider education as seriously as we think of water resources or freeways. Why isn’t there a sense of urgency, and what can business and the professions and industry do to emphasize the urgency? I think we’ve got to engage Sacramento and the voters on these issues. I don’t see a solution that comes from a series of local, private efforts.”

**Bloom:** “Clearly, public funding is important and we need to place the crisis in education at the top of the public policy agenda. But I believe it’s industry that is going to drive that agenda, because industry is facing a shortfall of trained workers and California is at risk because the majority of university graduates that industry needs aren’t coming from within the state. As we’ve already discussed, industry is seeking graduates from other countries. Obviously, the government funds the state universities, and the state university system is excellent, as are the community colleges, but I think public education issues will be driven by...”
William Swanson: “Earlier President Baker mentioned the modeling of the U.S. educational system we did at Raytheon. We’re an engineering company and we decided to apply our technical ability to the problem, to determine what the priorities are for improving the system. Many people have great ideas for a solution, but the hard part is figuring out which idea will ‘move the needle.’

“By modeling the educational system through a dynamic flow analysis, we found that teacher quality was the highest dynamic mover among the different variables. We also found a factor that we call a ‘stick rate,’ which refers to how many of the students who enter a university engineering or science or math program actually stick through the program for the necessary four or five years. The number of students who complete these programs is currently insufficient, but increasing the number by a few percentage points would have a huge impact on the educational system. This deficit in STEM-program completion is disturbing, when you remember that each year Cal Poly’s College of Engineering is turning away 400 students with 4.0 grade averages and high SAT scores. It makes you angry when you have a business that employs tens of thousands of Californians and you realize that gifted students are not being admitted to the university and won’t graduate in engineering.

“I do agree it’s time for industry to become involved in the educational system if we want our businesses to remain in California. Otherwise, industry will have to move to another state that understands the importance of public education, which would be unfortunate because California is a very rich state and can support education. I would add that the whole educational problem is becoming too bureaucratic and that we need to decide on definite goals to focus on. In the universities, in industry and in the legislature there are people who do want to improve the system, but we have to choose specific objectives and work with discipline to complete them. Again, we really are in a crisis situation when the university has to turn away excellent students who have a background in science and math.”

Hackwood: “That is precisely the message that people in Sacramento need to hear. Legislators are more likely to listen to industry than to academics or representatives from our K-12 schools. The agent of change is industry, but the mechanism for achieving change will require that industry work in conjunction with lawmakers and the public school system.”

Swanson: “I think industry needs some help in knowing whom to address and where its influence can be most effective. There are a lot of passionate people in the aerospace industry who would be eager to explain to Congress what improved public education means for the competitiveness of their business. We need talented employees and we are going to go to where that talent is but I don’t want our industry to go offshore.”

Bloom: “If you read through Bill Gates’ testimony before Congress, you realize that the members of the committee admit that the education problem is not new, that they’ve discussed the issue before. Obviously the problem hasn’t been solved, not enough thought and money have been invested in a solution. Bill Swanson’s point is that now we need to fully engage the problem.”

Bonnie Konopak: “In addressing our concerns in Sacramento, we should talk to the secretary of education or the California Department of Education, because one major problem in our schools is that teachers have to teach to the K-12 content standards, and in science those standards are at least 10 years old or more, depending on the subject area. A push from industry is needed...
to introduce a fresh perspective on science instruction. I have had conversations with Provost Durgin about Massachusetts and looked at that state’s K-12 content standards, which incorporate engineering into the curriculum. We don’t have anything like that in California. There are other states whose standards might serve as models that we could study and consider implementing here in California. Again, I think some of these changes must be driven by industry, which senses future trends and the requirements for responding to them. Instruction in our schools needs to reflect the evolving science and technology environment.”

**Richard Hartung:** “On the one hand I hear that Cal Poly turned away 400 4.0 students from the College of Engineering, and on the other I hear that the pipeline is failing to supply sufficient numbers of science, math and engineering students. Do we have a capacity problem at Cal Poly or do we have a pipeline problem in our public schools? There seems to be an inconsistency here.”

**Baker:** “The capacity problem results from the fact that the programs are not funded.”

**Hartung:** “What good is it to fill the pipeline if we turn away qualified students?”

**Baker:** “The point to make is that industry has to help government to understand what the priorities are, that you can’t cut support for education and still expect to receive the benefits of education downstream. Education is an investment. At Cal Poly we’ve experienced the government’s unwillingness to properly fund education. In October, the governor announced that California needed 20,000 additional engineers over the next 10 years. But the budget he introduced cuts funding to the higher-education system by 10 percent. Support for higher education has been reduced consistently every year. Providing sufficient money is not a priority because no one is pressuring those people who make the decisions.”

**Hartung:** “It seems to me that the first thing to do is provide space at the university for those students who have already emerged from the K-12 pipeline. We need to find a way to educate the 400 well-qualified students who can’t get into Cal Poly.”

**Baker:** “I wouldn’t draw the conclusion that because Cal Poly turned away 400 4.0 students that those students didn’t continue their studies at other universities in the California system. At the same time Cal Poly is turning students away, there are openings in engineering programs at universities throughout the state.”

**Hartung:** “Do these 4.0 students really fill those empty seats at other universities or do they decide to go into law and business? Don’t we have to properly serve the STEM students graduating from the K-12 pipeline? I understand that politics is involved and that there are empty seats and full seats, but we need to recognize that we are losing well-qualified students because we don’t have the capacity at Cal Poly to accept them.”

**Oaxaca:** “You have to factor in the reality that Cal Poly is a premier institution. Cal Poly receives 35,000 applications and a large percentage of those students will attend other schools in the California State University system.”

**Stephen Ciesinski:** “Our conversation keeps pointing toward the fact that as a nation and state we don’t have a comprehensive education policy.”
to the shortfall, we obviously have a recipe for disaster."

**Swanson:** “The funding cuts are especially serious when you look closely at the universities and how they have to operate. It costs a university twice as much to educate an engineer as it does to educate a major in business or the liberal arts. When state budgets are cut—and Cal Poly isn’t unique, it’s going to happen across the United States—the needs of the university are going to be counted in numbers of students, not by disciplines. Businesses are organized to recognize cost differences for different functions, but how do you persuade a state to adequately fund an engineering school that is twice as expensive as other university programs?”

**Mitchell Suarez:** “In my opinion, the strong message to take to Sacramento is that the state’s budget policy puts California into a vicious downward spiral. Each year California has to invest more and more in prisons and less and less in education. We have to convince the state’s leadership to change their way of thinking and start investing more in education—specifically in science, technology, engineering and math—so that we can break out of our descending spiral. Leaders in Sacramento have the idea that the costs of different services are equally justifiable and that everything has to be cut across the board. That’s a simplistic way of thinking that has to be addressed and I encourage everybody in this room to join together, to send a message with one voice, about the central importance of education.”

**Keith Fox:** “Part of our challenge is to act as a broker to help businesses advocate for education. We need to remember that a two-phase approach is required for educating more scientists and engineers.

“First, we have a short-term problem in the California State University system that involves the need for higher funding—an acknowledgement of the greater costs of educating engineers as compared to liberal arts students—and for increased differentiation among the different campuses in terms of their areas of focus. As a business community we have a responsibility to help the state understand that the present strategy is flawed. That Cal Poly had to turn away 400 excellent engineering students is unacceptable.

“Second, we need to address the K-12 STEM pipeline issue, to find ways to interest more students in STEM classes, to improve instruction and aid our teachers.

“My father taught for 31 years, he was a child of the Depression who took advantage of the GI Bill and became a teacher in electronics and industrial arts. I see an opportunity for us to craft a similar story for returning military veterans of the present conflicts, and especially for returning Hispanic-American veterans. We can draw upon our own history as a nation and its public policy that educated those who served our country in wartime. At Cisco I helped start our Network Academy—we spent $10 million to $15 million a year developing and maintaining that curriculum and now it’s in 10,000 schools in 200 countries. Industry can assist our society and become an advocate for the kind of programs we need.”

**Robert Leach:** “I’d like to bring some hard numbers to our discussion. In 1998, the average lifetime gross domestic product generated by an engineering graduate in the United States was $5.1 million. For every would-be engineer we turn away from the university we are losing $5.1 million in lifetime gross GDP from our national economy. The 400 engineering students Cal Poly turned away would generate $2.05 billion in their lifetimes as engineers.”
Our country can’t continue losing $2 billion a year in future GDP because of poor decisions we’re making in education. The problem is clear and we have to address it now, to make a near-term investment to reap the long-term, significant return.”

Mary Crebassa: “I want to return for a moment to Bill Gates’ testimony before Congress. He said that every engineering job required the support of five to six other employees who were liberal arts majors. One job lost in engineering creates a domino effect that involves five or six non-engineering graduates. As a liberal arts grad working for Microsoft, I wanted to point out the interconnectedness between engineering and other disciplines.”

William Harris: “The conversation about the crisis in education has been going on for 25 years and the lack of urgency or response from government suggests that we are doing something wrong, that we are not communicating effectively. To mobilize this country, to gain people’s attention and make the argument for education easy for politicians to understand, we need to frame our approach around our national economic security. When you hear that our industries can’t hire American employees, that jobs are going to be shipped to other countries, you become concerned. We want to blame the schools, to blame the system, but without government leadership that provides coherence among the differing views and groups the debate will continue until we become a failed economic system. I would challenge us to stress education as the foundation of our national economic security in the 21st century.”

Ciesinski: “I would like now to ask our two presenters for closing comments.”

Wise: “Thank you for the opportunity to talk to you today. In discussing what we need to do to develop a diverse scientific and engineering workforce, I think we’ve agreed that an interest in STEM careers begins early in the lives of our students, and that there are areas within our educational system that we can focus on for improvement in the near term.

“Again, in confronting the problems with education we’re faced with a crisis and an opportunity—the awareness of crisis provides the opportunity. However, there has been a worsening crisis in education for between 10 and 20 years. Until our education shortage becomes personal to each and everyone of us—like a shortage of water or food, or rising gas prices—I don’t believe we will hear the necessary level of concern from the American public. Maybe part of our work is to help communicate that our educational system is in crisis, to urge industry, government and the universities to work together, to collectively tell all Americans that the crisis is real.”

Bloom: “Charla has an excellent perspective on the problem. Her suggestion that we need to make the crisis more personal is interesting—it’s true that education isn’t something most people ‘touch’ every day, it’s not as tangible as rising fuel prices or a water shortage. But our discussion proves that everyone here has a strong opinion and that we all bring genuine passion to the debate. The emotion that we feel and express about our state and nation’s education problem can be converted into a plan of action to address and improve the system, and as a group we at Cal Poly can make a positive impact for change. Thank you for allowing me to comment on this very important topic.”
In his introduction of Richard K. Miller, president of Franklin W. Olin College of Engineering, Stephen Ciesinski noted that Miller is widely recognized as one of the leading innovators in U.S. engineering education. Ciesinski indicated that this presentation would offer a new paradigm for educating America's future engineers, based on the following propositions:

- “To arrive at solutions to complex 21st-century technological and societal problems, citizens and workers will necessarily be conversant with the methods and theories of science, technology, engineering and mathematics, while also being capable of viewing those problems in the broadest human and cultural context.

- “As a result, we are obligated to rethink our approach to education and to consider developing a new liberal education that brings together science and technology and the arts and humanities in a new synthesis.”

For the last nine years, Miller told his audience, he has led an effort to rethink engineering education, an endeavor that has required him to consider the future of engineering and the role that engineers will play in the coming decades.

“The grand challenges that are facing us today include slowing global climate change, developing sustainable energy sources, maintaining security in an age of cultural collision and terrorism, providing affordable quality health care for all, and ensuring equitable water and food distribution. Technology will help address all of our important problems, but it is critical to understand that technology alone will not solve any of them.”

Technology is an “amplifier” of human intentions, Miller suggested, and technology’s effects can be “positive or negative, deliberate or unintended.” Decisions to pursue new technological developments must be balanced with economic, social, political and cultural concerns to avoid unforeseen, adverse consequences. As modern technology advances in developing countries, the world will become increasingly interdependent, so that national and international issues will merge.

“Ecological choices made in Beijing already affect environmental conditions in Los Angeles. And disciplinary interdependence, like geographical interdependence, will increase with the spread of technology. The applications of new innovations will become the focus of products and markets, with the artistic and cultural dimension of technologies providing the new frontier. For example, the iPhone contains very few technical inventions or new parts manufactured by Apple, yet its market appeal is enormous, because customers perceive it as ‘cool.”
Increasingly, in the global marketplace a product's attractiveness will overshadow consumer interest in its raw technology, Miller said. "Discerning the cultural acceptance and demand for a product or service must be given central importance in planning for the future." Paul Horn, the former vice president for research at IBM, recently pointed out that most innovations will result from the integration of existing technologies. A large fraction of IBM's business is now based on services, and the company has begun to develop an entirely new field: Services Science, Management and Engineering (SSME). This emerging area of technology and business depends on a technical staff that is capable of solving engineering challenges in a range of cultural and social environments.

The University of California, Berkeley, and North Carolina State University already have research programs in this developing field. Miller said, as technology and its marketing and services become closely linked to the personal, individual dimensions of prospective customers.

"People skills are now central and successful engineers will develop a new artistic style or look and feel that has as its hallmark an appeal within a cultural context. The new engineer will have some of the talents of a Picasso, be adept in the practice of technical design and contribute more than calculating correct answers for differential equations or questions involving thermodynamics."

How will our society solve a myriad of difficulties that demand more than pure engineering expertise? Miller asked.

"Only engineers have the necessary background in natural science and mathematics and the practical, problem-solving and synthesis skills to make technological innovations and developments within complex circumstances. The National Academy of Engineering assumes that engineers should take the lead in finding solutions to 21st-century problems, but only if engineers broaden their horizons."

Miller referred to the National Academy’s recent reports on The Engineer of 2020: Visions of Engineering in the New Century project, which stress that engineers must think creatively and display ingenuity as well as leadership and teamwork skills, communicate effectively, have a sense of professionalism and practice ethical reasoning, be equipped for societal and global contextual analysis, and understand a variety of work strategies.

"Educating engineers with this higher calling will require new thinking, new attitudes and priorities, and broadened definitions. First, the colleges of engineering need to ask, ‘Are we attracting the right people to address the challenges of this century?’ Almost all current engineering students chose the field because of their proficiency in math and science, but few were recognized in high school for their creativity and ingenuity or their leadership, teamwork or communication skills. In educating tomorrow’s engineers we have to give more weight to these characteristics in our admissions process."


"Gardner’s research indicates that all humans have at least seven largely independent intelligences: linguistic, mathematical or logical, spatial or visual, kinesthetic and bodily, musical, interpersonal, and intrapersonal. The first two of these intelligences, which I label as ‘analytical,’ are measured by most standardized college admissions tests and are the abilities universities seek in their applicants and foster in their students."
Spatial, kinesthetic, and musical intelligences are closely aligned with the arts and with creativity and are developed primarily through experiential learning, while the interpersonal and intrapersonal intelligences are the foundations for persuasion, management and teamwork skills.

“Gardner observed that test scores do not predict students’ success after they leave college and must establish a career. There isn’t a one-to-one correlation between scoring 1600 on the SAT test and inventing a technology that improves the world. Gardner’s framework of multiple intelligences also provides a new way of thinking about diversity: Many students come from backgrounds in which they have developed multiple kinds of intelligence that will allow them to succeed in life, whether or not they possess the analytic skills that are the focus of college admission procedures.”

Our universities must produce graduates who have a wider scope of intelligence, Miller believes, if our engineers are to achieve their full potential.

“We have to acknowledge that other intelligences in addition to the analytical are important to engineering, a change that will involve a cultural breakthrough in our engineering schools. Next, we must attract more students who possess these additional intelligences. Third, we should redesign our engineering programs to cultivate each of these seven different abilities.”

To enroll more broadly talented people, Miller said, the definition of engineering may need to be expanded using Gardner’s description of intelligence: “The ability to solve problems or fashion products that are of consequence in a particular cultural setting or community.”

“Each of Gardner’s kinds of intelligence matches this definition or did at some point in the history of human development. People who take initiative, demonstrate resourcefulness and make a positive difference in the world fit a profile that describes the engineer. Sometimes, but only sometimes, this involves invention of new technologies. This broadened definition may also apply to professionals in non-engineering disciplines.

“Many of the best business graduates, for example, should perhaps also be included in our new vision of engineering. Challenges don’t come with tags that say ‘I’m a thermodynamics problem,’ or ‘I’m an accounting problem.’ Overspecialization hampers communication between business and engineering schools—the disciplines use a different vocabulary and their students develop different self-identities that have to be corrected when graduates enter industry.”

Miller suggested that changes in engineering education, to produce engineers with wider interests and abilities, include:

- Defining engineering more broadly, as a profession that solves problems, creates products of value for society and appeals to the altruism of today’s young people who are eager to improve the world
- Identifying engineering applicants who have a balance of analytical, creative and leadership skills, using interviews or essays to select qualified candidates
- Employing “spiral learning,” in which short periods of work on advanced experimental projects alternate with short periods of theoretical study to fill gaps in knowledge, a strategy that leads to improved retention of course material

Miller then outlined creativity and design, entrepreneurial thinking, and teamwork and
communication as the three fundamental skill areas for the engineer of 2020.

“Creative thinking, innovation and design will be needed on an unprecedented scale to address the large challenges that we face. Design is at the very heart of engineering and one of its major differences from science. Scientists ask ‘Why?’ as they seek to understand the world, while engineers ask ‘Why not?’ as they seek to change it. The word ‘engineer’ is often a verb—the word ‘science’ is always a noun. The essence of engineering is to create or to invent or to make.

“At Olin College, we believe that engineering and art have much in common and that we can learn from the successful techniques of art and design instruction. ‘Studio thinking,’ the subject of Harvard University’s Project Zero, which studies the nexus between learning art in a studio format and later achievements in ability and creativity, may have an analogue in team-based projects in engineering study. We know that project-based learning develops a self-confident, can-do attitude that is essential for success in engineering, research and entrepreneurship.

“Projects in which interdisciplinary teams are focused on solving common problems—for example, the invention of a device or a system—require that students construct authentic mental models of the principles involved. They learn in the laboratory, not by memorizing or taking multiple-choice tests. The device needs to work and if doesn’t you have to find out why.

“Finally, being creative takes courage. The essence of creativity is seeing things that other people don’t—innovating and inventing require that we visualize new things. But the social consequences of possessing a new vision are often negative and may cause creative persons to become alienated from a society that doesn’t share their sense of possibilities. Young people are particularly vulnerable to feelings of isolation and many of our most creative individuals may stifle their good ideas in order to conform. Our universities need to improve the learning environment, to reduce social resistance to creative thinking and minimize the onus placed on the frequent failure that is often an initial part of the pursuit of original ideas.”

The new engineer, Miller urged, must combine creativity with an aptitude for entrepreneurial thinking.

“To become innovators, engineers must recognize commercial opportunities and deliver the technical idea from the laboratory to the marketplace. Commercializing a new idea requires a knowledge of business, a sense of drive and initiative, and the ability to communicate and persuade—skills which fall under the category of entrepreneurial thinking.” Thomas Edison, one of America’s great entrepreneurs, was also one of its great innovators. He believed in the social value of his idea, even when the best light bulb he could make stayed lit for only one minute, and engaged investors in his vision to help him commercialize it.”

The ability to work effectively as a team member and to communicate clearly is a talent that engineering employers seek in their new engineers, Miller emphasized.

“Today’s engineering graduates must work successfully in diverse, multidisciplinary teams that include non-engineers and individuals from different cultures, age groups and levels of achievement and authority, some of whom may be working from different time zones or countries. Learning to work in teams doesn’t happen automatically but depends on interpersonal and intrapersonal intelligence. An essential sensitivity to the group dynamic allows engineers to lead as well as to follow, to
work toward consensus decisions, and to trust others and build lasting relationships. Willingness to work for the team’s success rather than for personal gain is a key attitude.”

Miller suggested that engineering colleges might adopt instruction techniques used in business schools, where students learn how to work together to solve problems.

“Practicing effective communication has long been a shortcoming for engineers and is usually the first and major concern that I hear from employers. Most communication problems have nothing to do with writing or grammar but instead involve issues more familiar to a marriage counselor. Engineers need to make eye contact, to communicate in ways that make for trust and solid, longstanding relationships. Students have to learn to become good listeners, and engineering schools must find ways to encourage better interpersonal relations, which means teachers must improve their own ability to communicate. The learning environment is best when faculty members demonstrate teamwork by example and are enthusiastic and clear in their speech and manner. Students pick up these cues and are strongly influenced by them.”

As the president and first employee of Olin College, Miller has taken part in the evolution of a new way of engineering education. Chartered in Massachusetts in 1997 by the F. W. Olin Foundation, the college was founded on unique precepts: students pay no tuition, as a reward for dedicating themselves to careers in science and engineering; Olin has no academic departments; faculty receive no tenure; and the college is dedicated to the principles of continuous improvement and innovation.

Olin College has an enrollment of 300 students taught by a faculty of 35, and grants bachelor of science degrees in engineering, mechanical engineering and electrical engineering. Admission to the college requires attendance at a weekend of extensive interviews, which are designed to identify candidates who are creative and have teamwork, communication and interpersonal skills. (Applicants are first screened by standard written tests in math and science.) More than 90 percent of Olin enrollees graduate and the student body is divided almost evenly between women and men, making Olin one of the most gender-balanced engineering schools in the nation.

The design process, Miller said, forms a central framework throughout all four years of the Olin program. “All students participate in design-build team projects starting in the first semester on campus and most students are involved in team-designed projects for at least six different semesters. All seniors must complete a year-long team design project that is financially sponsored by a corporation, usually at a level of $50,000. Students have a paying client who expects results, which is consistent with Olin’s emphasis—we teach students how to be engineers, not about engineering.

“At the conclusion of each semester, all students deliver a lecture or a poster presentation based on an aspect of their educational program to everyone in the college community. These presentations are part of our Olin Expo event and are evaluated by approximately 100 professional corporate and academic visitors to our campus.”

The first two years at Olin provide a broad foundation in mathematics, natural science and engineering design. The curriculum is organized into integrated course blocks comprising three coordinated courses taught by a team of three faculty members who sometimes work together in the same classroom.

“Our deliberate objective is to embed the material in context to minimize disciplinary boundaries. Our hope is that students will
be unable to say whether they are learning math or physics or engineering as they work to solve the interesting problem at hand."

A reserve block of time is set aside in the junior year so that every student can complete a study-abroad experience. "Nearly a fourth of Olin graduates choose to participate in the 'study-away' program, a number that far exceeds the national average of about 5 percent of American engineering graduates who have studied abroad."

A growing number of Olin students use the study-away time to start a business off campus. To receive an Olin diploma, every student must begin and run a business for a semester.

"About 30 percent of Olin's students are deeply influenced by this experience and continue their business studies, which culminate in a senior capstone project in entrepreneurship. We've devoted a building called The Foundry to house the students' new ventures, and more than 10 percent of our alumni develop their own businesses after graduation."

Olin has an unusual intellectual property policy, Miller explained, which allows inventors to maintain complete control over their inventions. "We may offer advice and guidance but we want our students to become successful entrepreneurs and own and profit from their own efforts."

The college also requires every student to complete a capstone project in the arts, humanities and social sciences, and each semester about 35 percent of the Olin student body are cross-enrolled at Wellesley College, Babson College or Brandeis University.

"The object is to ensure that our students make contact beyond a concentrated group of future engineers and learn to talk and work with teams of people from other fields."

The heart of the Olin College experience, Miller underlined, isn't found in the syllabus and the course descriptions but rather in the relationships between the faculty and the students that encourage a love of learning and of how to create. He agrees with Charles Vest, the president of the National Academy of Engineering and former president of MIT, who believes that "making universities and engineering schools exciting, creative, adventurous, rigorous, demanding and empowering milieus is more important than specifying curricular details."

Miller concluded his presentation with a brief portrait of one recent Olin College graduate, Leighton Ige.

"In 2006, Leighton started and ran a business from his dorm room that was evaluated at more than a million dollars before he graduated. His company's business plan won the $5,000 Muller Prize awarded by Babson College. After commencement, he moved to Hong Kong to be near suppliers and hired a classmate to open an office of his new company, Salubrion, in San Francisco. Leighton has just launched a new product—a sophisticated clock and timer—as part of his product line of yoga equipment."

[Miller displays clock to audience.]

"In place of a second hand is a Japanese character that sweeps out the passing seconds. The clock is selling very well at $100, a price well above the cost of production. The technology is nice but the 'cool factor' that attracts customers is the sound of the alarm that signals the end of your yoga session."

[Gong resonates for several seconds.]

"This unusual, long-lasting sound is the result of many weeks of research and many iterations in the digital recording studio. Leighton learned to listen and to observe his
clients closely and to be obsessive about the things that mattered to them. The sound of the gong is a part of a time-honored tradition within Asian culture and elicits an emotional response among yoga practitioners. The sound is what makes the timer special within the Asian marketplace. Leighton has become an artist in designing a technical product—at 24 he has learned the art of innovation and the art of entrepreneurship while studying engineering.

Stephen Ciesinski thanked Richard Miller for his address and asked Susan Hackwood to provide commentary on the changes taking place in education for engineers.

“When I was a young researcher at Bell Laboratories,” Hackwood recalled, “we used to have what was called a ‘pots and pans meeting,’ in which our boss would ask, ‘Is the project that you’re presenting a ‘Plain Old Telephony System’ or ‘Pretty Amazing New Stuff’? I think what Richard Miller has described to us today is amazing and new. We’ve learned how engineering is changing and the ways in which engineering students need to be prepared to meet the goals of this century, and we’ve learned about the really good programs that Richard and others are developing to inspire and equip our future engineers.”

Miller’s emphasis on educational change to transform our universities’ engineering schools and educate a new generation of creative, entrepreneurial, socially aware engineers couldn’t be more timely, Hackwood said.

“At the National Academies meeting I attended last week with members of Gathering Storm—the initiative to address America’s falling numbers of engineers, scientists and technical workers—I learned about a new research university being launched in Saudi Arabia that has an endowment of $10 billion, a sum the Massachusetts Institute of Technology required 142 years to accumulate. Next year 200,000 Chinese students will study abroad, primarily in science and engineering, and many of them on government scholarships. In the United Kingdom, my home country, government investment for non-defense research and development will increase by 25 percent over the next few years, the kind of commitment that has not been made in the United States. And recently, I read in the magazine Nature that India will start 20 new research-intensive universities in the next decade. In addition, a multi-year Indian initiative is under way to make that country a global nanotechnology hub.

“The point is that the competition is not standing still. Other countries are doing really unusual things and we should laud them for their efforts, which will help remake the world. At the same time, we need to mobilize ourselves if we want to be leaders in technological innovation.”

Hackwood praised Miller’s presentation for his emphasis on what she called “adaptation” rather than on “mitigation.”

“In the political, cultural and educational climate we have in California, change often means that we try to lessen the ill effects of the status quo. Discussions on ways to meet the state’s greenhouse gas-reduction targets may involve ideas on how to make a Hummer run on hydrogen. Another extreme, ‘mitigating’ viewpoint might suggest that everyone ride a bike. Adaptation requires a different mindset altogether, and Richard’s ideas have suggested some valuable adaptation methods.”

Hackwood then turned to the perceptions our society and especially American youth have of engineering.

“As a field, engineering has not been particularly attractive or exciting to the general public, but its unromantic reputation is not at all necessary. How many of you have seen ‘Iron Man,’ which is the ‘coolest’
movie playing? Its hero is a mechanical engineer. Television’s ‘CSI’—Crime Scene Investigation—has run for eight years, and now ‘Numbers,’ whose protagonist solves crimes by mathematics, is the most popular prime-time Friday program. ‘Numbers’ is written by a mathematician on the faculty at Caltech, and a math graduate student from Caltech is the show’s ‘stunt double’ who performs the hero’s calculations on the whiteboard. The actor couldn’t write the equations fast enough for the cameras because he had studied only algebra, and so we have a new career for someone trained in mathematics.

“Of course we have a long way to go in improving the popular view of engineers, mathematicians and scientists, but there are glimmerings of change appearing in the media that are humanizing the technical fields and showing the drama and color of the vital work done in the nation’s university, government and industrial laboratories.”

To respond to Miller’s insistence that engineers need an increased cultural understanding and a better knowledge of the consumers who will accept or reject their innovations, Hackwood described two incidents that illustrate the importance of informed entrepreneurship and an eye for pleasing design.

“The National Academy of Engineering is a wonderful institution, but a couple of years ago it started a Web site called ‘Engineering Girl.’ My two teenage daughters gave it an emphatic ‘thumbs down.’ The site didn’t attract them, it didn’t have Richard’s ‘cool factor’ and failed to gain their attention and interest them in its message.

“In February I was at the AAAS [American Association for the Advancement of Science] meeting in Boston and I was browsing among the souvenirs that the association sells. I noticed a very nice T-shirt that had for its printed design images of the human genome. Unfortunately, all of the T-shirts were tube-shaped, a style my daughters—and most of their friends—would never wear. Again, the ‘cool factor’ was missing—the science and engineering mindset had failed to properly identify and understand its customers and provide a product that appealed to them.”

In concluding her remarks, Hackwood acknowledged that the American youth culture has undergone dramatic changes and that our education system must effectively respond to new sensibilities shaped by innovations in technology and mass marketing.

“Today’s kids really do think differently, and if you ever wonder whether your child is an ‘alien,’ the answer is ‘Yes.’ Our children have grown up using their thumbs for communication and are unable to imagine an existence without a cell phone or the Internet. For years, they have been multitasking, absorbing multiple forms of communication at once, taking in a host of simultaneous images and spoken and written words along with music. They also have short attention spans. John Morgridge in his speech last night noted that Cisco has determined that 15 minutes is the optimum length for an instruction session. I believe that current neuroscience with its studies of synaptic connections is confirming that the brains of young people are structuring themselves differently from the ways our brains developed when we were our children’s age.

“Obviously, our pedagogy must change, because today’s future engineers really do think differently from those of previous generations. I believe that Richard Miller is on the right track in describing the new engineer, the new challenges of engineering and the changing perception of the field. We do need to develop more practical and relevant methods of teaching to attract and educate a diverse group of students.
with a range of talents whose experience has caused them to think and learn in ways fundamentally different from our own.

Ciesinski thanked Hackwood for her comments on Miller’s address and asked the audience for their responses and questions.

**DISCUSSION**

**Question:** “At Olin College, is consideration of the ethical implications of engineering practices a formal part of the curriculum, or a subject that arises spontaneously in interaction among students and faculty?”

**Richard Miller:** “I wish I could say that we have a four-year core theme welded into the curriculum that addresses ethical implications, but we don’t. Instead, we have a work in progress. I am team-teaching a senior seminar, with the presidents of Babson and Wellesley colleges, which we call ‘Issues in Leadership and Ethics.’ I developed the course, studying relevant material and texts for a couple of years before I invited the two presidents to join me. A conversation about values at the university level can be a ‘third-rail’ issue, a dialogue not easy to effectively develop. You cannot preach at students. We often invite high-profile guest speakers, whose career experiences at times forced them ‘into the crucible,’ and they relate first-hand the crises that confronted them.

“Our students heard Jim Ashton, who had been one of the chief engineers on the F-16 fighter jet at General Dynamics before he was promoted to lead engineering operations for the Trident submarine at Electric Boat in Groton, Connecticut. Ashton discovered some inappropriate activities and went to the Navy and later to ‘60 Minutes,’ testified before Congress and brought down the whole Trident project. Ashton described what it was like to be a whistle-blower and the personal and career repercussions of disclosing ethical violations.

“Another of our speakers was Larry Lasser, who had been the CEO of Putnam Investments in Boston, a company that underwent dramatic changes and in the last few years has essentially disappeared from the financial scene. In 2003, evidence emerged that a few of Putnam’s 13,000 employees were involved in after-hours trading. Lasser talked to our seminar about heading a disintegrating company—the title of his presentation was ‘Things I Wish I Had Known.’

“The central theme that emerges in our seminar is that most ethical crises are not sudden, black-and-white problems that one day appear on your desk and confront you with a clear choice between right and wrong. Neither blatant dishonesty nor clear-sighted moral intelligence develops overnight. Ethical awareness is the product of an evolution, an accumulation of smaller choices over a lifetime and has to do with right attitudes and discipline. At the present time, our senior seminar at Olin doesn’t involve all of our students, but the issue of professional ethics remains an extremely important one.”

**Jaime Oaxaca:** “Can other American universities emulate the Olin College model of high admission standards and practical, intensive instruction?”

**Miller:** “Your question raises several issues. I’m often asked if our college’s success depends on our especially gifted students and the size of our endowment. My answer is that the fundamental ideas at work at Olin can be set in motion at schools that have very small budgets and students who have not previously excelled in their coursework. Let me give you two examples.”
“The Big Picture Company is led by Dennis Littky, who [with co-founder and co-director Elliot Washor] has started about 60 alternative high schools in economically depressed areas across the United States. You may have seen the feature film made about him and his project. Littky went to schools that had graduation rates below 25 percent and by shifting the curriculum to project-based learning succeeded in engaging students in entrepreneurial thinking that stressed self-generated projects and businesses. Now the schools have model graduation rates and their students go on to college. Littky is using the same instructional principles we employ at Olin College.

“In New York City, The National Foundation for Teaching Entrepreneurship was begun by Steve Mariotti, a Wall Street executive who became concerned that young people in Harlem and other areas in New York were not taking advantage of the opportunities that America offered. He created a program in universities throughout the country to train high school teachers to teach entrepreneurship. Mariotti’s program is based on many of the same ideas we’ve had success with at Olin—meeting the students at their present level of expertise, encouraging their communication skills, looking for and developing multiple intelligences, providing project-based learning and promoting the transformative power of a can-do attitude. Students discover the relevance and importance of math and science and learn it along the way.

“Are other engineering schools around the country interested in what we are doing? Absolutely. One of our management problems at Olin is providing campus tours for the many interested visitors. Olin has made a major impact because of the boldness of our approach, even though we’re a small college. Universities in other countries are studying our program and are changing their curriculums to match many of our techniques. There are seven Korean universities in Korea that have been observing the Olin model. One of them has already created a program called The Edison Institute for Teaching Entrepreneurial Thinking and Entrepreneurship within an engineering school where the labs go unheated in winter. I would say that abroad there is a much greater commitment to change and innovation in education than there is in the United States.”

Stephen Ciesinski: “In our first session, Charla Wise outlined four areas of focus—the K-12 pipeline, the culture within our public schools, the science and engineering curriculum, and the global perspective. In terms of Charla’s emphasis on diversity, I would like to ask Bill Durgin to comment on his experiences at Cal Poly and his prior work at Worcester Polytechnic Institute.”

William Durgin: “We need to think about what Cal Poly might look like in 20 or 30 years because soon we will have to set its future directions. At Cal Poly and most other American universities where engineering is taught, there is resistance to change, an inertia that is not easily overcome. Richard Miller was in an enviable position at Olin College, because he could begin with a clean slate, but the question of how we are going to improve engineering instruction remains and Richard has discovered some very important elements that suggest ways for a positive evolution. I would refer to Bill Wulf, the former president of the National Academy of Engineering, and what he said some years ago on the issue of diversity in engineering. He said that we had to bring multiple perspectives to engineering issues, a strategy that Richard is pursuing at Olin. We have to teach students how to look at problems through different lenses and to think about issues from different points of view.
A common complaint among engineers is that we don’t have enough influence in American society. Perhaps we bear some responsibility if our views don’t receive a proper hearing. We may not be preparing our students to assume the leadership roles that would allow engineers a stronger voice in determining the decisions we make as a nation. The questions I am most anxious to address here at Cal Poly are, ‘How can we make fundamental changes in the way we presently teach engineering?’ and ‘How can we best prepare our students for their future responsibilities?’

Before I came to Cal Poly, I was at a university that took a few preliminary steps in the direction of change, some 15 or 20 years before Olin was founded as a center for innovation. I think that America and its engineering schools are now poised for major changes. The imperative is to think carefully about how we teach now and how we can teach more effectively. Other countries are very good at copying what we do well and if we make the assumption that our present strategies are marvelous and don’t need to evolve, our universities will go the way of the old textile plants in New England. At Cal Poly, how are we going to adjust our curriculum to prepare our engineering graduates to take the lead in solving 21st-century problems?

Linda Halisky: “As dean of the College of Liberal Arts at Cal Poly, I am interested in the role that the arts and humanities and social sciences play at Olin College, and especially in the ways Olin’s successful program might be implemented at a very large university.”

Miller: “I am passionately convinced that students in both engineering and in the arts and humanities and social sciences can be enriched by cross-disciplinary study.”

The people at Sloan are convinced that to become a successful business executive you need to learn to think creatively. The faculty at SMFA have developed a special project-based, free-form learning exercise to help students improve their creative thinking skills. However, in talking to the provost I learned that SMFA’s interactions are primarily with other art schools and that most other universities are unaware of their program to enhance creativity.

“At a school like Cal Poly, I think that the communication between the different disciplines should begin in the freshman year. Projects that take place early in a student’s collegiate career, particularly design projects, offer the most accessible entry points to an interdisciplinary program. Beginning students in introductory courses don’t need the expertise required in advanced engineering courses, and it is amazing what students can learn from classmates who have a different perspective.

“At Olin College we’ve instituted a course called User-Oriented Collaborative Design, a requirement for every sophomore and part of the ‘design stream’ of classes our students take. In this course students do studies of potential client groups to find out what kinds of technological innovations would improve their clients’ daily lives. Multidisciplinary teams that occasionally include Babson and Wellesley students are assigned to a client group for five weeks to live in their clients’ world and learn from them what their needs are.

“One of these teams went to Massachusetts General Hospital in Boston, where for five weeks they shadowed operating-room nurses. They went into the OR with them, they ate lunch with them, they watched the nurses fill out paperwork. The purpose of the study was to design one or two new technical devices that the nurses suggested would make their work at the hospital easier.
The team drew a diagram of a prototype technical device, made a Styrofoam mockup and listed the technical specifications that described how it worked, its weight and preferred color and its estimated cost. The class teaches the importance of learning to listen to others.

“Now, the central point of this story about the hospital is that the Wellesley students, who were majoring in sociology, heard things from the nurses that the engineering students didn’t. At first, the future engineers may have been a little arrogant, perhaps imagining that their own SAT scores were higher than their teammates’, although of course the students at Wellesley are excellent. They may have thought that their ability to solve differential equations gave them an advantage over students who were used to taking ‘easy,’ ‘non-scientific’ classes in the arts and humanities. But the students from Wellesley relied on their developed interpersonal and intrapersonal skills, which were of prime importance in the hospital environment, and became the acknowledged heroes of the team. The wall between the disciplines collapsed as the engineers realized the importance of a different perspective. In this case, perhaps the Olin students gained the most new knowledge. But I do think that Cal Poly is in a wonderful position to help many students who aren’t pursuing a science or engineering degree to learn much more about the nature of science and technology.

“One thing we’ve just done at our college is to create an Olin certificate in engineering studies for students who are at Wellesley College, Babson College and Brandeis University. The certificate is the equivalent of a minor, an academic approach that you might consider here at Cal Poly. Our certificate program offers an opportunity for students to discover technology and engineering as they pursue their majors in other fields.”

**Warren J. Baker:** “Could you comment on how the framework of engineering curricula is shaped by the Carnegie accreditation structure and how at Olin College project-based learning is combined with just-in-time instruction in a second subject? For instance, how would you integrate just-in-time statistics instruction with project work, so that passive, lecture-class learning is avoided but necessary statistical knowledge is acquired and implemented in the project environment?

“What we’ve learned at Cal Poly in surveying our students is that an enormous amount of learning takes place outside of the curriculum, a fact that supports your view that the curriculum itself is not the major element in an effective engineering education. The need to structure the program as a set of requirements determined by the earning of Carnegie units may be an important reason that many of our engineering students decide to switch to another major. The inflexible structure doesn’t allow them to express the creativity that is part of a free-ranging learning experience not arbitrarily divided by disciplines and their strict schedule of courses.”

**Miller:** “We have experimented with innovations that relate to co-curricula and just-in-time learning in the project-based approach and continue to investigate methods of co-curricula instruction. At Olin nearly every student in nearly every semester is involved in a team-based project. About 25 percent of all academic work is a team-based exercise that relies on the spiral learning process I’ve described. If you Google ‘spiral learning’ you will find many links to educational theory, but the basic idea involves exploring possibilities beyond the traditional lock-step, Chapter-1-through-Chapter-20 linear passage through a textbook, which is a good description of traditional statistics instruction. On the third day of class a student working in a laboratory can encounter in an experimental context the need for statistics and begin to
understand what ‘uncertainty’ means.

“For example, you can weigh yourself on a bathroom scale three times in a row and be amazed that the scale registers three different weights. How can three different measurements be possible and how can you describe mathematically the range of readings? A couple of weeks later you work with a module on probability theory and fundamental statistics, and then you launch ahead into a project that runs directly into a brick wall because you’re lacking some further knowledge of statistics. Now you’re motivated and you can circle back to statistics and learn more in order to successfully complete your project.

“Woody Flowers, a good friend of mine at MIT, did some study of the school’s graduates and discovered that students who had passed courses in which they were tested and graded on their mastery of textbook material hadn’t necessarily learned the material. The assumption that following the Carnegie curriculum structure of engineering instruction will naturally lead to a positive outcome is contrary to the facts. A more authentic, personal engagement with the material often produces a deeper and more accurate mental picture of the engineering principle at hand, even if the project-based learning experience doesn’t immediately engage all of the engineering aspects involved.

“Some years ago Steve Director, who headed the electrical engineering department at Carnegie-Mellon [CMU] before he became a dean at Michigan, did some revolutionary things with his colleagues at CMU. They decided to reduce rather than increase the number of credit hours required for a bachelor’s degree in electrical engineering at Carnegie-Mellon, despite the fact that new inventions and innovations are continually expanding the field and adding new subject matter for study. Steve said that engineering instruction is no longer about trying to teach students everything, because to cover all of the different material means less and less time is spent on individual topics, and the solid knowledge students absorb may actually be reduced. He decided that the university needed to teach students how to learn, and his insight changed the paradigm.

“Instead of introducing all of the aspects of electrical engineering, at Olin College we teach the field by requiring students to take some classes for which they haven’t taken all the prerequisites, and the new topics are learned as they become necessary to solve problems. This approach was heresy some years ago but it can be transformative. Most of the work engineers do at Lockheed or Raytheon is new—there are no prerequisites for creating what no one has done before. If there were, the invention would already exist and the companies wouldn’t be interested in funding research to develop it.

“I want to mention a very important element of the co-curricular dimension of engineering instruction. I’m convinced that engineering students belong in some sense to a special needs group. They need attention outside of the classroom—guidance and encouragement in becoming active members of the greater student population—because the social dimension of their education is crucial.

“I’m going to do something risky now by relying on my memory of a study undertaken some years ago by a superb private undergraduate institution that specializes in science and engineering. They studied characteristics of their entering freshmen, graduating seniors and alumni five years after graduation, using the College Student Survey administered by the Higher Education Research Institute at UCLA. (This survey is administered nationally and statistical results for many thousands of students are available for comparison.)

“They found that freshmen at their college—all of whom were engineering, math or science majors—had a level of self-confidence in their academic abilities that
was much higher than the national average. Their scores were at the 90+-percentile level, as I recall, indicating that these first-year students were confident about their intellectual talents and believed that they would excel in their studies, whether the subject was math and science or English, history or political science. But when these engineering students were asked to rate their level of social self-confidence, they ranked below average for all students, at about the 45th percentile. These were students who in high school were deeply interested in science and math and paid close attention to their studies, a behavior pattern that set them apart from many of their classmates and usually didn’t add to their social popularity. They often spent extra time studying on weekends for the SAT, while other kids were out having a good time. As a result, when they entered college they were socially less experienced or adept than freshmen in other disciplines.

“Expanding the subject matter of courses and including non-engineering students can help integrate engineers into the mainstream of college society.”

Richard K. Miller

“In addition, I believe there is some evidence that suicide rates among engineering students are higher than the national average. This troubling phenomenon has been studied case by case at MIT and elsewhere. Their reports indicate that suicides are rarely a result of academic pressures, even at very demanding schools like MIT. The underlying cause often involves a broken relationship, a problem in dealing with other students or with parents or a romantic partner. It is clear that our engineering students need help in learning to deal with their personal interactions.

“Another worrisome statistic is the skyrocketing number of incoming freshman who because of depression or other psychological issues are taking prescription psychotropic drugs. About 20 to 30 percent of freshman nationally are now prescribed these medications, which allow them to attend college but can also leave them vulnerable in the social pressure cooker of student life. Weekends mean parties, and alcohol is always present. If you’re on medication you’re not supposed to drink, but you don’t want to admit to classmates that you’re taking prescription drugs. Students feel pressure to drink or to stop their medication, which is the worst thing they can do. Student life programs and supervision of dormitories are important, and so are co-curricular experiences that help engineering students become more comfortable with relationships and interact with students from other disciplines. Expanding the subject matter of courses and including non-engineering students can help integrate engineers into the mainstream of college society.”

Baker: “You make a very good point. In the 1960s I was associated with an engineering college whose design requirement for graduation included the stipulation that a student from the liberal arts and one from business had to be part of the design team. Engineering students were exposed to other perspectives, socialization issues came to the fore as the team began to work through the project design, and the business input helped to determine whether the design would be commercially successful. The non-engineers improved the engineering students’ design and showed them how to interact with the business community outside of the university. The curriculum helped the future engineers learn about engineering and the world.”
Stephen Ciesinski introduced the speakers for the forum’s third session, David McLaughlin and Mark Russell.

“With support from the National Science Foundation, David McLaughlin of the University of Massachusetts and Mark Russell of Raytheon have created a noteworthy collaboration around what David has described as a grand quest to develop the fundamental knowledge, enabling technologies and system-level prototypes for a dense-radar network technology that has the potential to revolutionize how we detect, track, forecast, warn of and respond to hazardous weather events.

“For our final Baker Forum session presentation, let me offer as context two observations:

- “Residing as it does at the intersection of multiple science and technology-based applied disciplines, the polytechnic university is perhaps uniquely positioned to support and assist industry and government in finding solutions to contemporary challenges.
- “Formal partnerships among industry, government and university entities can provide structure for these collaborations.

“We look forward to hearing how David McLaughlin and Mark Russell’s experiences in pursuing their own important project might help universities such as Cal Poly to better understand the elements required for successful industry, university and government collaboration.”

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is a partnership among the University of Massachusetts, the Raytheon Company, the National Science Foundation (NSF) and several other organizations. CASA’s goal is to transform the observation of and response to extreme weather events like tornadoes, hurricanes and flash floods through the development and deployment of new, dense-radar networks.

Russell began the dual presentation with a capsule narrative, describing how CASA has its origins in a relationship between university and industry reaching back more than 20 years.
before the center’s inception in 2003.

“The University of Massachusetts and Raytheon are founded on engineering fundamentals. The Raytheon Company has 42,000 engineers among its 72,000 employees and is led by an engineer. More than 1,000 University of Massachusetts graduates with bachelor of science degrees and more than 250 UMass graduates with master’s or doctoral degrees work at Raytheon. In the past the university and Raytheon had worked together on innovative advanced studies and had solved important technical problems, but both the university and the company wanted to create a partnership that had greater scope, that would have more than $100 million in support, involve eight universities among its 20 partners, and work to solve a very large scientific challenge.”

McLaughlin commented that in 1980 the University of Massachusetts and Raytheon Company had developed a new graduate program in microwave engineering, in response to Raytheon’s need to gain further sophisticated training for its microwave engineers.

“The microwave program proved to be strategic. The university began to align a portion of its faculty hiring with industry needs, and the increased communications with Raytheon—they’re only 100 miles apart—helped develop a university culture that valued a hands-on practicality, an experienced-based learning environment not unlike Cal Poly’s.

“In 2000 the University of Massachusetts and Raytheon decided to extend their collaboration beyond microwave engineering, into more systems-level research and educational concepts, as a way of advancing the missions of both organizations. The vision statement, which we wrote together, announced ‘a sustainable multidisciplinary partnership advancing mankind’s ability to observe, understand, predict and respond through fundamental inquiry, new technologies and systems integration, while providing educational opportunities for a new and diverse generation of leaders.”

This plan called for a long-term, intellectually broad partnership between the university and Raytheon that would produce leaders in engineering who would focus on a set of contemporary problems involving the need to observe and understand current conditions in the environment and to predict future events and devise practical means of responding to them.

“That kind of ‘problem space’ encompasses a wide range of contemporary problems,” McLaughlin said. “We see the modern research enterprise as an orchestrated linking among fundamental inquiry, new technologies and systems integration that prepares this century’s most gifted engineers.”

In 2002 the Center for Collaborative Adaptive Sensing of the Atmosphere was on its way, after the venture among the University of Massachusetts and Raytheon and their partners won a highly competitive quest for funding from the National Science Foundation.

“Gaining support to establish an engineering research center involves the most grueling competition that applicants encounter in seeking NSF funding,” McLaughlin pointed out. “Only four awards were made from among 122 letters of intent, but the winners each received $43 million to be paid out over a decade. The NSF rigorously reviews each center’s yearly progress and in the third year one of the centers lost its support because of a failure to achieve its announced goals.”

McLaughlin told the forum audience that he
and Russell had spent three years in writing the grant proposal, which the university and Raytheon funded at a cost of $500,000.

“The dollar amount to develop a grant proposal was not large for a big company, but very large for a university, so the cost was shared. The grant writing process required many meetings and extensive background preparation.”

The University of Massachusetts had several important motivations in seeking support for the research center, McLaughlin said.

“The faculty and the administration were in agreement that we wanted to broaden our base beyond microwave engineering education and develop a leading system-level program in research and education. We had a history of working with Raytheon and knew that sensing and radar made up a core business area for Raytheon and that the company required employees who could think and function at the systems level. The university and Raytheon had developed a bond of trust that would allow them to work together on a large proposal.

“We also saw the opportunities offered by a project that involved radars and radar networks that would enhance the nation’s hazardous-weather response. The project would increase the public’s interest and trust in engineering and show younger people how engineers could address a difficult and important problem and through their work improve the lives of Americans. Mark and I went to the commonwealth of Massachusetts, described how the CASA project would lead to future educational and economic development for the state, and received $5 million in public funds. Three years of hard work culminated in winning the coveted NSF Engineering Research Center grant, and after five years CASA is by all accounts a highly effective engineering research center that has grown to include 20 different industry, academic and government partners. As CASA advances, we continue to learn new things about fostering and sustaining partnerships.”

Successful, long-term collaborations resemble ecosystems, Russell said, and require that each partner contribute valuable assistance and receive desired benefits.

“CASAs benefits to the university were obvious—the opportunity to conduct basic research and develop new technologies while training their students and preparing them for the workforce. The partnership offered the creation of a learn-by-doing environment similar to Cal Poly’s.

“The advantages for Raytheon were also evident. If a company creates value, it creates markets. Raytheon is currently involved in a competition that involves the future of all aircraft control, weather and homeland security radars, a kind of ‘bundled’ technology that continues to evolve and was not fully apparent when Raytheon joined in the CASA partnership.

“And the National Science Foundation, as an agency of the federal government, is concerned with promoting the public good. Developing a dense-radar network to better predict and warn the public of hazardous weather conditions obviously was valuable to all Americans.”

In a partnership ecosystem, Russell said, each participant receives a different benefit.

“Everyone gets something and contributes something. The return is not equally distributed every day but the abiding precept is that you should put in exactly the same amount that you take out. CASA has worked so well and produced technologies worth hundreds of millions of dollars because each partner received what it needed. No one player was dominant, no partner received most or least—a result that my daughter might describe as ‘way cool.’”
McLaughlin next underlined the importance of the partnership ecosystem, extending its definition to include not only mutual advantage and cooperation but also a shared sense of responsibility and duty.

“The core element in effective partnerships is the mutual ownership of a real problem, and the real problem that we were taking on was hazardous weather events and how to better protect the public. In a typical year in the United States there are about 1,000 tornado strikes. Under the present warning system 800 tornadoes are detected and 200 are missed. Each year about 5,000 evacuation alarms are issued and 4,000 of those are false alarms. The current system has an 80-percent detection probability and an 80-percent false alarm probability.

“The cornerstone of this technology is an observing and warning system that comprises a network of Doppler weather radars deployed across the United States. The Doppler radars are physically large and high-powered and are deployed about 230 kilometers apart. They are able to detect raindrops from hundreds of kilometers away from their antennas and do a marvelous job of mapping the middle and upper parts of the atmosphere.

“However—because of the curvature of the Earth and the far distance between each radar installation—the system is unable to monitor the weather in the lowest three kilometers of the atmosphere. This radar blind spot is the area where weather events are born, where the atmosphere drags on the ground and kicks up storms, the area where storms impact people. The present weather-predicting paradigm is to make aerial observations and enter them into numerical models, to attempt to anticipate what weather will occur at the Earth’s surface where we live. That is today’s state-of-the-art weather-forecasting technology, which detects 80 percent of tornadoes and issues false alarms 80 percent of the time.”

There is broad scientific agreement, McLaughlin said, that the Doppler system’s inability to “look down low” is the factor that limits the accuracy of current tornado predictions and warnings.

“The innovation that we are pursuing in the CASA project is a rather straightforward idea. We want to supplement or replace the present network of 150 big radars with thousands of small radars that can be deployed on cellular telephone towers, rooftops and other infrastructure. The closer spacing of the new radars will avoid the obstruction caused by the curvature of the Earth and allow us to look directly at the lower atmosphere in high-resolution observations. If we can make the new system cost-effective, we will revolutionize our ability to observe, forecast and respond to hazardous weather events.”

McLaughlin noted that in addition to the engineering challenges associated with the radar itself, there are architectural problems to be solved that include managing the system’s many resources and the high volume of data, and the technical problem of data transfer and a complex user-interface component.

“How do we send the right data at the right time to all of the system’s various users who are downstream of the weather event? Data users include scientists and trained forecasters, emergency managers who may not be professional forecasters, the media and the public. Many different groups and individuals will use the system’s information to make response decisions to the hazardous event. Our central intellectual challenge is in designing and deploying a system that can sample the atmosphere where and when the user need is greatest and issue reliable warnings that the public trusts and responds to appropriately.”

The solutions to the different problems posed by such an ambitious project are to be found, McLaughlin explained, through
CASA’s working on three planes of engineering research.

“There is the bottom plane, a plane of fundamental understanding, of basic research that creates new knowledge. This plane involves not only electrical engineering and an investigation of how electromagnetic waves interact with the atmosphere, but also sociology and psychology. We need to develop new and greater knowledge about how individuals and organizations respond to severe weather hazards, how people use warnings and what motivates them to take action. We want to understand the impact of false weather alarms on future behavior and to learn more about the human factors involved in the group and individual responses to extreme events like Hurricane Katrina. This vital first plane of basic research in fields such as electrical engineering and computer and behavioral sciences is within the ‘comfort zone’ of academic faculties but it also presents a barrier, what I call ‘Barrier #1,’ which has to be overcome for the success of the CASA project as a whole.

“On the middle plane we create CASA’s technology—the radars, the protocols for moving data around, display, and signal processing. This second plane is obviously an area where industry is capable of making substantial contributions.

“The top plane is systems integration, where the different levels converge, hardware and software meet, and all of the project’s elements are adjusted and placed together and we learn whether CASA’s central concept will be successful.”

McLaughlin briefly described Barrier #1, which he encountered at the project’s first plane of research.

“At the research stage we’re bringing together people from different disciplines, with their own perspectives and backgrounds. Engineers, computer scientists, meteorologists, economists and sociologists all have the characteristic mindsets, methods and expectations of their given field. Building complex systems requires weaving together a range of skills and points of view and integrating the products of each discipline’s approach and sense of priorities. The central point I want to stress is that although depth of knowledge is necessary and universities are configured for the pursuit of knowledge in depth, this knowledge in itself is insufficient for solving contemporary problems. We need more than that and the challenge for universities is for their faculties and students to learn to work with people with different skills to achieve effective cross-disciplinary collaboration. Industry, of course, knows how to do this, and can help to teach the teachers.”

Russell recalled that at the beginning of the CASA project he and McLaughlin thought they understood how to develop cooperation among the several disciplines.

“We knew that everyone had to be enthusiastic about the project and that everyone had to contribute. However, we needed a framework to make progress. Even when we talked about solving an interesting radar problem and the resulting algorithms, parts and products that Raytheon could use to enhance its technology and services, we failed to get people to cooperate or even to continue to attend meetings. That’s when we decided to take a Raytheon systems engineering course, which was created within Raytheon to help join together all the systems architects, and we actually ran the class at the CASA universities.

“Michael Malone, the dean of engineering at
the University of Massachusetts Amherst, took our class and we required that he do the math and he thoroughly enjoyed it. He and other deans participated and became inspired. As the deans took part and rolled up their sleeves, all of the professors and then all of the industry people came along. We ran this class multiple times. Massachusetts, Colorado, Oklahoma and seven other universities are now offering elements of the class that we developed at Raytheon to encourage the different disciplines to work together. We required that everyone learn the general systems engineering thought process, and the experience has allowed the CASA team to solve problems involving technology, operations, users and policy."

The challenge of providing many different users with weather forecasts in a format each could understand, trust and use effectively underscored the importance of successful partnerships both within CASA and with the entities CASA was designed to serve, Russell said. "We had to talk to the people whose job it is to use weather data, who look at computer screens and interpret the data. We had to learn about their perception and analytical processes, how they absorb and organize information and about the most effective ways to present our weather data. Delivering our weather observations in the clearest manner will allow a Federal Aviation Administration [FAA] operator or a meteorologist working at a storm center at the National Oceanic and Atmospheric Administration [NOAA] to more easily analyze our information and make an important decision with increased confidence and speed."

“We like the idea of a complete ecosystem as a model for creating sustainable partnerships and we understand the importance of all the participants achieving and sharing in success. Our project has solved problems in hard science and advanced university research as we’ve worked toward producing practical results that will benefit people in America and around the world. For example, my wife grew up on a farm in the Midwest, near a small town that was destroyed by a tornado, and with the CASA project my wife’s relatives have taken special interest in my work. The Texas Medical Center has become involved with CASA because their area is vulnerable to flooding, and another partner, the University of Adelaide in Australia, has a weather problem related to uncontrollable wildfires. It’s important to remember that systems like CASA’s tend to be adopted internationally before they are implemented in the United States. In fact, the first installation of our radar network will probably be in Canada, to predict wind and snow. The Canadians are very receptive to new innovations in air traffic control and weather forecasting, just as they are to wind-generated electricity technology. Our strategy at CASA has been to look to those places that are eager to install our system and receive its benefits."

CASA’s ultimate challenge in gaining acceptance, Russell believes, is not the funding of the infrastructure, which will require billions of dollars, but winning the cooperation of important partners. "At times it was difficult to gain the confidence of administrators of our air traffic control and weather forecasting systems. After an unpromising beginning, we’ve made progress and today the charters of these entities now contain commitments to resolve differences and to use a wideband multifunction infrastructure. The successes we’d already had in solving some of the large scientific problems buttressed our case. We created a student testbed at the University of Puerto Rico and have had numerous business opportunities to create value within many different industries. When you view a list of all the members of our collaboration you realize that we are working..."
simultaneously in many areas and that the partners are pursuing aspects beneficial to reaching their goals while contributing to the overall success of CASA.”

Within CASA’s complex ecosystem of mutual contributions and rewards, it is sometimes difficult to isolate and define the partners’ exact roles and responsibilities, although the two pillars of CASA’s successful collaboration remain clear and allow the team’s successful work to unfold, Russell said.

“Partnerships depend on trust, and on the ability to both lead and follow. In the dozens of interactions among CASA partners, industry, academia and government have alternated in taking the lead to provide direction in areas where they have special experience and expertise. When NOAA and the NSF attended one of our briefings and led the conversation, we knew that they were in agreement with our scientific work and that they had joined our ecosystem, which only works when each partner thrives.”

McLaughlin described a CASA feasibility and proof-of-concept demonstration that proved important in providing metrics for measuring the project’s progress.

“As we began the center in 2003, we set as a three-year goal the installation of an end-to-end radar network in Tornado Alley in Oklahoma. We chose Oklahoma because of the large number of tornadoes per square mile, the high incidence of other violent weather, and the many people in the state who are intensely interested in weather and are consistent users of hazardous-weather warnings. The many types of radar in the network each had to cooperate with one another, allowing the system to automatically and constantly reallocate its resources as the weather and the needs of a group of users changed. It was a rather complicated system to complete in three years—the project required that we build the technology and develop the software—but it works and is demonstrating capabilities that are fundamentally beyond the present state of the art. Our radar network has been reviewed numerous times, by the National Science Foundation and National Academy panels.”

CASA’s radar system allows for very-high-resolution, low-angle views of tornadoes, which are a vast improvement upon the images the technology now in use produces, McLaughlin said.

“The older system shows pixels that represent intense radar echoes from rain—during threatening weather the pixels will often form a classic, hook-shaped image. People who live in the plains, in tornado country, have heard of hook echoes. The hook suggests that a tornado may be developing and human spotters are then deployed to make a visual sighting, to confirm that there is a tornado. The 80-percent false alarm rate results from the radar’s hook echoes that in reality do not signify an actual tornado.

“The CASA radar sees the umbilical cord at the end of the funnel cloud and can zoom in with a spectacular and unprecedented spatial resolution, to show in fine detail what is happening right down close to the ground, producing low-level radar pictures beyond the capability of any other current system. The radar data is conveyed to a variety of users, from forecasters to emergency management and ultimately to the media and the general public.”

McLaughlin emphasized that fulfilling the goal of building an operational, breakthrough radar network within three years was a milestone for CASA and provided a specific focus for the center in terms of its own work and identity and its relationship with users of the new system.

“Envisioning and completing the project galvanized our efforts as a team and
demonstrated the success of the complex enterprise that is CASA. The radar network also required us to give real definition to general terms like ‘user’ and ‘user need’ and ‘end-to-end.’ We now have a functioning infrastructure that supports our inquiry, and our work is leading to new research on the limits of atmospheric predictability and into how people respond to warning information during uncertain, potentially hazardous weather conditions.

“The most important thing that came from our work is that we’ve shown the world that our concept works. We’ve deployed a unit cell of a larger system whose concept has been proven successful, and in the process demonstrated to ourselves and to the external community that CASA can execute innovative, complicated projects of social and scientific value.”

Russell observed that the success of the CASA radar network in Oklahoma, which was predicated on the efforts of veteran researchers, led to a greater emphasis on involving students in CASA’s development—many future engineers who gained valuable training and made impressive innovations while working on CASA testbeds have become talented new CASA personnel or high-tech industry employees.

“Our Tornado Alley project was the product of approximately 30 first-rate researchers from universities in Colorado and Oklahoma, the NSF and NOAA, as well as other institutions and agencies. Although many patents were granted and important new science established, we realized that we weren’t sufficiently recruiting students to help our team, which led us to set up a series of testbeds.

“The University of Puerto Rico installed a testbed with a handful of radars, and in the process the students invented network, reflectivity and retrieval algorithms. One of the biggest challenges in developing a functional radar system is in fusing multiple radars and understanding how their data should move through the system. Companies like Lockheed-Martin, Raytheon and Northrop Grumman work hard and employ large teams to work on the problems of directing radar data. The students in Puerto Rico had no cables to put together, so they made their network wireless, and because there were no tornadoes they designed their system to detect hurricanes along the Puerto Rican coast and inland flooding. With a minimum of resources, the students working with the testbed detected weather, solved algorithmic problems, wrote and published scientific papers and won patents—universities working with CASA are able to benefit financially through intellectual property agreements [IPAs]. Teams trained through this project at the University of Puerto Rico now work for Raytheon and other high-tech companies.

“At Raytheon we’re convinced of the tremendous value of working with universities. Some of our best advanced-programs people have come from our relationships with the 75 universities that we collaborate with on projects like the Puerto Rico testbed that Dave and I instituted. Raytheon understands that university partnerships are mutually beneficial, especially in the current environment of rapid innovation. Our company built many of the early weather radars and air traffic control systems and we remain competitive in these areas, even as we realize that a paradigm shift must occur at Raytheon if we are going to continue to successfully evolve. We are going to merge the weather and the air traffic control systems because no one government agency can afford to fund the entire project.

“At first it was uncertain whether such an ambitious system could ever gain the needed support, but our success with the low-angle radar network in Oklahoma has
been persuasive to previously uncertain potential partners with whom we are now in serious consultation, especially because of the close connection between air traffic control and hazardous-weather detection systems. International Business Machines (IBM) and Hewlett-Packard are interested in data service aspects of our ‘dial-a-resource manager.’ We have a partnership agreement that balances the need to maintain an open source for some technologies generated within CASA while keeping control of our own intellectual property. When we compete with other defense companies we can win the product systems, but we also need partners to help proliferate the innovations we’ve made.”

In working with universities, Russell said, Raytheon has learned an especially valuable lesson: how to build for thousands of dollars parts and equipment that would ordinarily cost Raytheon much more.

“With the universities, with the aid of students, we built some radar panels. Instead of using ceramics, the students used low-tech cloth boards, and in place of high-tech chips they made very-low-power chips. They were able to construct a panel for an order-of-magnitude lower cost than conventional approaches. These panels could be placed on cell towers and rooftops and medical centers and produce good radar coverage, because you could use some of the algorithms to share the data.”

CASA’s success in gaining support for a large-scale radar network has been aided by attracting representatives from weather forecasting agencies and the FAA as well as other entities seeking the timely implementation of the system’s architecture.

“We are no longer talking about a radar,” Russell stressed, “or an algorithm. We are talking about an architecture for making decisions, an innovation that directly addresses the biggest problem our users have. The solution is not necessarily in the science but in the process of decision-making itself.”

Russell again underlined the central role of the universities in CASA’s work and in the creation of successful partnerships with industry and government.

“A group cannot collaborate unless it has a shared environment in which to work, and the university provides the ideal place where different parties can meet. Representatives from industry and governmental agencies can come to a university and sit around a table and together make progress. (If the meetings are held at Raytheon or at IBM, for example, the participants tend to fall back into ‘corporate speak’ and begin to focus only on policies and procedures, especially when each party is accompanied by legal representation.) At some point we were all able to determine what each partner wanted from the CASA collaboration. Everyone wanted something different and all of us wanted to operate in different spaces, using different aspects of the CASA research and technology. For instance, Raytheon is not going to become involved in certain commercial medical markets, but we do want to compete in other big markets. Private sector weather service partners are primarily interested in receiving good data for their forecasts.

“Our CASA ecosystem works well—our university partners have profited, hiring more professors because of the certainty of funding from the NSF and other agencies, which allows each university to fine tune its core competencies and to further excel in its chosen areas of focus.”

McLaughlin noted again that CASA had its genesis in the experience of two organizations—the University of Massachusetts and Raytheon—working together for a long time. As CASA evolved, it displayed those attributes of good partnerships that are essential to success.
“Most important is that partners have a shared vision and that each partner understands the different missions and motivations of the other partners. I didn’t grasp that at first, in our CASA work—I thought everyone cared primarily about building radars, but actually the areas of interest were much broader than that. The university has a mission, industry has a mission, government has a mission, and we had to create a collaboration that was greater than the sum of its parts, to unite differing but complementary missions, toward the achievement of a goal that had multiple aspects and rewards.

“...In putting together a partnership in which everyone contributes and benefits, you have to gather complementary points of view, while identifying and understanding the parties’ differing approaches to problems and their individual patterns of working toward solutions. For instance, universities operate on one time scale, industry functions on another, while policy decisions are made on still another scale of time. These differences need to be acknowledged and factored in to sustain a partnership that depends on mutual trust and a sense of a shared destiny. The partners must ‘invest’ with one another, whether the investment is made through commitments of time or through student exchanges or a variety of other mechanisms. The partners must have a stake in one another if the partnership is going to flourish over time.

“The terms of any partnership need to be set in writing, but once that’s accomplished the work becomes much easier, especially if you remember that, as Mark mentioned, there’s a time to lead and a time to follow. In the CASA partnership, the role of leader continues to alternate—I’m good at handling certain challenges, while Mark or one of our other partners is better at solving different challenges. As CASA has evolved we’ve found that this shifting sense of leadership serves the center well.”

In closing, Russell paid special tribute to McLaughlin’s leadership at CASA and to the importance of university teachers to the future of engineering.

“Many people in industry are eager to work to form partnerships that create value for their companies, and many individuals within government agencies are enthusiastic about funding projects that advance research or technology in their area of interest, but it is rare that a professor steps forward to form a collaboration, as Dave did at the University of Massachusetts. I believe that the number one need of a polytechnic university is for its professors to take lead roles in promoting and organizing partnerships with industry and government.

“Dave is the director of CASA. He works harder than he needs to, and while his duties may not earn him a Nobel Prize, his efforts have resulted in the development of some very important scientific and engineering advances. There is an ongoing debate about what is required to become a successful engineer. Of course, you need enthusiasm and a sense of the fun of engineering. But above all, you need a passion for engineering.

“We knew that we could eventually solve the challenges of our CASA radar project, even when the board from the National Academy expressed some initial doubts about the feasibility of the plan. The key question in our minds was, ‘Do we have the passion to complete the work?’ When I visit university campuses, I’m looking for a professor who has a glint in the eye, the glint that tells me that he or she has the passion for engineering and the completion of ambitious projects. The key university person is most likely not going to be the dean or even the president but a professor who is willing to step forward and acknowledge that there is a real road to climb.”

“I believe that the number one need of a polytechnic university is for its professors to take lead roles in promoting and organizing partnerships with industry and government.”

Mark E. Russell
Stephen Ciesinski thanked David McLaughlin and Mark Russell. He then asked Keith Fox for comments on their presentation.

The story of the CASA partnership, Fox said, offers a valuable model for how successful academic, industry and government collaborations germinate, grow and prosper.

“We’ve heard how CASA had its beginnings as a personal relationship and then became an institutional relationship that continued to gain size and momentum over time, an expanding network of partnerships founded and sustained by partners building trust in one another and in their project and its many possibilities. David and Mark clearly made the point that CASA’s achievements have depended as much on good, trusting relationships as they have on radar technology.

“At Cal Poly, we’ve had an ongoing conversation about our curriculum and the need to teach more than just engineering as we help our students develop relationship, communication and business skills, those sometimes-overlooked but indispensable talents that are required to start any partnership and sustain it over time. David and Mark aptly highlighted many of these necessary abilities that involve an awareness of others and their needs and capacities and that include a business acumen based in good common sense.”

Emphasizing the importance of partnerships and of partnering skills and of making the idea of partnership an integral part of Cal Poly’s learn-by-doing culture will require the leadership of the university’s faculty, Fox said.

“Cal Poly’s faculty need to assume responsibility for understanding the nature of partnerships, how they begin and continue, and the metrics that are involved in judging and maintaining the progress of a partnership. Valuing partnerships with industry and government agencies and other universities is not only important for Cal Poly as an institution but especially for its future graduates who will become engineers and enter the workforce. I was lucky enough to work for Apple Computer and Cisco, two companies that place a high value on a culture of partnership and the need for understanding your core competency and for setting up partnership processes that are ‘win-win-win’ for all participants—themes that David and Mark stressed in their presentation. ‘Win-lose’ partnerships can’t be sustained, a simple truth that many companies and institutions don’t understand and don’t train their employees to understand.”

Fox concluded his comments by seconding McLaughlin and Russell’s description of a successful partnership as a well-functioning and mutually beneficial ecosystem, and by suggesting that at Cal Poly ‘partnership’ should become a hallmark of the learn-by-doing credo.

“‘Ecosystem’ was an important term used often when I worked for Cisco and I think that the CASA project provides the epitome of a valuable ecosystem and shows how David and Mark’s core vision has created value for all the partners. The ongoing development of CASA proves that its organization promotes a process that constantly rewards good behavior. The CASA ecosystem works through checks and balances for the benefit of every good partner.

“Finally, I would just repeat the idea that partnering is a process, that partnering skills can be taught and instilled as part of the
culture at Cal Poly, and that ‘partnership’ should become one of the key words in our semantics as together we determine the way forward.”

Ciesinski thanked Fox for his commentary and then invited the forum participants to share comments and questions.

**DISCUSSION**

**Warren J. Baker:** "As engineering research centers came into existence in the mid-1980s, I chaired the National Science Board's Committee on Programs and Plans. Our program was intended to do the kinds of things that CASA is doing while addressing an area of special concern that we've talked about today and which is of particular interest to Cal Poly. In their first years the engineering research centers and the science and technology centers that followed them focused attention on the benefits that partnerships between industry and the universities would produce for undergraduates. As we make decisions about the future, we still often ask the question, 'What will be the benefit of this partnership to our undergraduates and to our philosophy of education, and how will the partnership engage our students in areas of study that will help them become more creative and well-rounded engineers?' Can you tell us what role undergraduates are playing in the CASA program and what educational benefits they've received from the industry/university partnerships that CASA has fostered?"

**David McLaughlin:** "Mark spoke in detail about our CASA testbed in Puerto Rico. The students actually own that testbed—we call it 'the student-led testbed.' CASA set the students the goal of designing an advanced flood-forecasting system on the island of Puerto Rico. The students were responsible for creating their own strategy, for clearly defining their plan in specific terms and carrying it out. They were free to make their own decisions, with the single stipulation that they would have to defend their work before the same panels and review boards that monitor all of the efforts of the CASA project. Some students wanted to shy away from this open-ended challenge, but other students were attracted to the freedom it offered.

“I think that the Puerto Rico testbed is a cutting-edge educational innovation because it provides a proving ground for leadership. Working on the testbed let the students experience what it means to stand up a real system, to give it definition and to formulate their own risk-mitigation strategy. For example, Mark mentioned their work on the small radars that are off the grid. These radars offered a challenging problem at first and when the students asked to employ some on-the-grid versions of the radar our answer was, 'Yes, if you think your adjustment will help you meet an intermediate goal.' The important point is that as graduate and undergraduate students they are working all of the right elements of a systems program and they own it.

“Another positive aspect of CASA's partnership with universities has been the recognition among faculty of how helpful undergraduates can be in research programs. In a survey I conducted just two weeks ago as I was preparing for an NSF presentation, I asked faculty members, 'What are your attitudes about undergraduates?' A striking number answered that they were becoming aware of how useful undergraduates could be in furthering research—a fact that in large part is based on undergraduates' facility with information technology. I would say that in many different ways undergraduate students have joined the mainstream of university research.”

**Mark Russell:** “The need for brevity prevented us from speaking in more
detail about CASA’s involvement with undergraduates. Massachusetts, Oklahoma and the rest of our university partners all have undergraduates gaining experience and training as they work on portions of the CASA system in labs and in the field. At a testbed in Oklahoma students were trying to determine why the system was malfunctioning, while all the senior CASA personnel were studying the data. It was discovered that things as simple as a cow rubbing against an antenna can cause the Doppler to change. Students are physically on site with wrenches and the radars, working first-hand and gaining experience that places them 10 years ahead of future engineers who lack hands-on training.

“If you can have a university like Cal Poly assign undergraduates to work for two or three years on these kinds of practical problems, they will gain knowledge that involves real systems. New engineers who have done this kind of work as part of their university studies operate at a level well above other graduates and are ready to assume positions that involve real responsibility at Raytheon and other companies. Dave and I have been almost shocked by the excellent skills these students have acquired by the time they enter the workforce. Our program is four years old and now dozens of engineers who worked as undergraduates on the CASA project are at Raytheon, where they’re valuable employees who from their first day have been working on real systems.”

Susan Hackwood: “I had the opportunity to run the first engineering research center for the first class in the late 1980s and early 1990s in Santa Barbara. We were working in collaboration with Raytheon on robotic systems for microelectronics. Ours was a brand-new program and although we didn’t have to jump through some of the hoops that David and Mark have described I did recognize in their narrative of the CASA project many of the experiences that I had at our center. I sat next to Dave at lunch and was reminiscing about the Santa Barbara center, thinking from a distance of two decades about the achievements that program had made, about the positive things that were created that wouldn’t now exist if that program hadn’t been in place.

“Two positive, unplanned outcomes resulted from our research, which focused on the automation of the microelectronics industry. One achievement was in vacuum mechatronics, in preventing moving parts within a vacuum from losing their lubrication. The other unlooked-for gain was that a number of our students went on to create the medical robotics industry by forming Computer Motion, a Santa Barbara company that was purchased by SRI and is now Intuitive Surgical, which has the market share for robotic systems for in situ surgery. These advances were the products of a creative atmosphere that allowed students to cross disciplines, a strategy that David and Mark are using at CASA. The connections they’ve made between different academic fields in their work on radar are much more sophisticated than our cross-disciplinary efforts of 20 years ago, but I sense in CASA a similarity to the Santa Barbara center, in the intellectual atmosphere and in ways of interacting that can produce surprising and unforeseen discoveries.

“My question has to do with two-year institutions. You’ve spoken about CASA’s involvement with four-year undergraduate programs, but because half of our graduates in STEM disciplines start their careers in community colleges I would like to know if CASA has any partnerships with two-year colleges.”

Russell: “Raytheon and many other companies are aware that too few engineering students at community and tech colleges complete their programs and continue their engineering education at four-year institutions. At an earlier session we discussed this problem of attrition, of the large number of engineering students who leave programs to pursue careers in other
fields. To help lower this high attrition rate, we have involved a number of community colleges in the New England area and around the country in the CASA project, although two-year students are not doing research and development. They help in other ways—they often work with a specific piece of hardware or software. The CASA association has captured the interest of many of these students and given them the encouragement they need to finish their engineering degree at a university.

“I want to make clear that the National Science Foundation is not the only agency that is partnering with two-year colleges and universities—almost every branch of our government, from defense to homeland security to health, offers programs with working outlines similar to those of the NSF. Polytechnic universities interested in developing projects with government agencies need to consider several questions. Does the university want to be part of a large partnership? Does it want to lead it or be a contributor? What benefits does the university expect to gain from the partnership? The answers require that the university form a vision of the kind of relationship it desires and of the research and work it wants to do. In developing CASA we've really tried to create a dialogue that explores the roles of universities and two-year colleges and of undergraduates in our network of projects and partnerships and I'm sure that Cal Poly could participate in any number of our efforts. We currently have 75 projects at Raytheon and many other corporations offer large numbers of partnering opportunities.

“I should say that in doing some background study on Cal Poly I noticed that for a university with such a range of talented undergraduates there did not seem to be a similar range of partnerships. I know that Cal Poly students are phenomenal and that Cal Poly graduates want to do hands-on work and become involved in interesting and important research and development. The goal of joining the talents and resources of the university and of industry, of the University of Massachusetts and of Raytheon, led Dave and me to work together and start CASA. Cal Poly could partner with the National Institute of Health, the NSF, with industry. I've been curious about the direction polytechnic universities were taking in terms of partnerships, one of the subjects addressed by this year's Baker Forum.”

Hackwood: “I would like to ask about the Engineering Research Centers [ERCs] within the NSF structure. My understanding is that usually a major research university develops an idea and then attracts a group of interested partners. Together the university and the partners decide a course of action for their project and then add the aspects of the project that involve education. Is anyone promoting four-year institutions for these partnerships or does the focus remain with the basic research universities?”

McLaughlin: “At the present time CASA's partnerships are all with research universities. I should say that the educational component of our university partnerships is more central than your description might suggest. We know that our funding from the NSF is for the purpose of furthering engineering education as well as for establishing a research center, that education is a very serious concern for the NSF. This is particularly the case with the Engineering Research Centers program at NSF, where the aim is to make a serious strategic impact on engineering education—broadening diversity and giving students systems and innovation perspectives that will enable them to compete successfully in a global economy. So all of our university partners are ultimately interested in benefits to engineering education. I would say that the educational element of our partnerships with the NSF and the universities was hard wired into our project's initial planning.”

Russell: “The importance of education to the NSF can be seen in CASA's winning
the intense competition for NSF funding. There were 144 parties interested in the four NSF grants—a very sizeable amount of money was at stake, with the possibility of perhaps hundreds of millions more over a period of time. We gained the approval of the NSF largely because of our partnership's firm grounding in education. An advanced study program started at Raytheon had been in place for years, involving graduate and undergraduate students from different disciplines. This university/industry background convinced the NSF that CASA's radar project would involve student researchers—our proposal was based on a history of developing academic programs and the strength of CASA's partnerships with different universities and industries. CASA won NSF funding because of its network of existing relations that involved the sharing of training, course development, personnel and technology. I'd have to say that the NSF is very serious about education when it awards grants.”

**Fox:** “David and Mark's presentation concerns the triangle of partnerships among the university, business and government. Sometimes when we discuss government partnerships we fail to remember that the NSF is not the only government agency that is funding research. I invest in alternative energy and have been meeting with the assistant secretary for the Department of Energy [DOE]. That department has put money into projects we're pursuing in partnerships with businesses and universities. I would encourage us to remember that there are other sources of government support beyond the NSF and its research grants.”

**Russell:** “Recently Northeastern University and the Raytheon Company won a science and technology award called ‘ALERT’ and the Northeastern team received tens of millions of dollars. Raytheon was only one of many companies that won research and development funding to work with about a dozen universities to further their science programs and increase training and research opportunities for their undergraduates. I've learned that the CIA, FBI and other government agencies recruit large numbers of Northeastern graduates, and the grant the university won reflects the government's interest in expanding and deepening science and technology studies for undergraduates who will join the government workforce.”

**Thomas Mackin:** “Last year Cal Poly participated with UC Santa Barbara, Stanford, the Massachusetts Institute of Technology, the University of Michigan and the City College of New York in putting together a proposal for an NSF research center devoted to alternative energy. In the process of preparing our plan we developed valuable collaborations with several innovative companies. Although we didn’t win the funding, we've made a good start in developing partnerships to pursue large grants for the work we want to do.

“We are looking for win-win-win relationships and have much to offer—Cal Poly educates more undergraduates than any of the research institutions that we partner with, our students receive excellent training, and we are especially strong in systems engineering. The research center that we proposed last year would have been an alternative-energy testbed that integrated and transitioned technologies developed at our partner institutions. Cal Poly is part of a homeland security center grant and I am currently working with UC Santa Barbara on establishing on the Cal Poly campus a center for collaborative engineering research. Our partnering efforts to win funding and set up research facilities are not well advertised, but Cal Poly is in the midst of the kind of processes that David and Mark have described in setting up CASA.”

**A. G. Kawimura:** “One of the exciting things that successful partnerships can achieve is a large-scale change in national policy. We are hoping this week that a farm bill may get signed in Washington. These
days most farm bills receive a lot of criticism for what they contain but this bill has some very good components. For the last three years our agency [the California Department of Food and Agriculture] has worked very closely with a number of federal agencies. Together, we assembled an uncommon group of collaborators who represent communities committed to protecting the environment, conserving natural resources, developing renewable energy, reducing hunger and improving nutrition. The current bill contains a great amount of money for important projects. In the past, Californians have felt that our state never received its fair share of dollars from agriculture legislation, but at the federal level progress is now being made. We plan to use the partnership strategies that we've formed in support of the farm bill to make other positive relationships and work for other good legislation, like reauthorization of the Child Nutrition Act that will be voted on in 2009.

“I'm particularly concerned with the challenges we face in confronting global warming. Whatever changes and adaptations we choose, we won't have the luxury of making mistakes, because we have only a decade or a couple of decades to solve the complex climate problem. In reaching the right solutions, partnerships are going to be very important, and especially for those of us involved with agriculture, with food, fiber and fuel. We need to find more ways to encourage brainstorming among the different fields and disciplines and to create more venues like the Baker Forum where we can discuss problems and look for the correct answers.”

Question: “I'm impressed that the government agencies were able to work together in support of the farm bill. My experience has been that empire building is common among federal agencies and that it's difficult for them to cooperate. I'd like to know if the agencies that CASA partnered with worked well with one another or whether their lack of mutual cooperation was something that CASA had to overcome.”

Russell: “Our success in working with the NSF and other agencies has depended on the concept of shared leadership, in deciding which partner was best equipped to solve a specific problem and effect the change we wanted. We can build multifunction wideband radar that can track and forecast weather and provide air traffic control able to monitor low-flying planes, but none of the individual agencies have funding streams that would allow a single agency to support the whole project. You have to determine how to work with each agency and to identify and communicate with the policy-makers who want to see your project completed.

“To build partnerships and gain funding for large projects requires a long haul: CASA’s development has been going on for years and will continue for years—it’s not something that can be accomplished overnight with one quick hit. In planning a major project you have to decide that over the next 10 years you are going to work toward a goal, set small milestones that you will reach along the way, and let your chosen path lead you to where you want to go. I commend Cal Poly’s efforts in pursuing its partners the NSF grant for alternative energy research, and for working with UC Santa Barbara to set up a collaborative engineering research center. You have to make a start and you have to compete to win. When Dave came to work with me at Tewksbury and Waltham, he said, ‘You guys come in awfully early and leave awfully late.’ I knew that CASA would have 144 competitors for the NSF grant. I looked at Dave and said, ‘This is what it's going to take to win,’ and his answer was, ‘Okay, we're in it.’

“It's difficult to put together partnerships, to develop ambitious projects and to gain a commitment from the different federal
agencies that they’ll cooperate with one another. An important factor was in our favor—the agencies saw a team that wanted to perform for them and from our standpoint that was a very positive sign for future success.”

William Durgin: “Could you describe the governance of CASA, how the different partners interact with one another to make decisions, set objectives and share the new knowledge that CASA develops?”

McLaughlin: “It’s a complex process that involves many individuals. We have a CASA executive committee, made up of 20 members from the academic world, and an industrial advisory board, which Mark and other representatives from industry serve on. I try not to make a move within the executive committee without receiving some support from the industrial advisory board. Governance within an academic setting can be a tricky thing—making decisions ‘from the top down’ doesn’t work well with university faculty. The executive committee is rather large, because we found that including more members allowed us to gain more support from more people within the universities.

“I once did a study, when the NSF wanted to determine if CASA was having an influence on curriculum. We asked faculty members on our committee several questions: ‘To what extent are your classes being impacted by what we are doing in CASA? Are they significantly impacted? Are you offering new classes or is CASA’s impact only minimal?’ The study found that the professors’ close involvement with CASA tended to have a great influence on the classes they taught. That’s when we decided to expand the executive committee, involving more faculty in CASA’s decision-making processes. Our academic partners now had more input into CASA’s planning and that resulted in them giving more emphasis to the CASA project in their classrooms, which strengthened our partnerships with the universities. Our committee can at times be a little unwieldy—we will all meet in Chicago this Friday to talk about some difficult issues—but the two-part CASA structure, with an academic and an industrial advisory board, has worked well.

“I should also mention that as an engineering research center CASA is closely engaged with peer advisory groups. At CASA we continually keep our colleagues in the greater community aware of our activities through an external science and engineering advisory board that we formed. The board is made up of members who are interested in and care about the CASA project—some of them serve on National Research Council panels. This advisory board keeps abreast of what we are doing and has real power—it meets with the NSF, which meets one on one with CASA’s industrial advisory board during the NSF’s annual peer review process.”

Durgin: “How do the government agencies in your CASA partnership share in decision-making? Do they work through your industrial advisory board, your executive committee of faculty members or through a third entity?”

McLaughlin: “Through the industrial advisory board. I should say that my experience in working with a large company like Raytheon served as a model for advancing the CASA agenda within NOAA, which is another large organization. At Raytheon we worked with an individual who knew how to navigate effectively within the company to further projects and accomplish goals. When we approached NOAA we knew that we needed to find someone who could steer us through that agency’s complex structure. That person was the director of the office of science and technology for the weather service, a person who had the ‘road map’ for radars and other technologies involved in surveillance strategy and was the
right individual to help CASA.’’

Russell: “It’s important to realize the effect on your partnership and your project when the different government agencies and laboratories join your effort. These new partners are also the entities that award contracts, decide where the funding goes, evaluate applicants and choose the winners. The leading administrators at NOAA and other agencies and the heads of laboratories like Lincoln Labs or the Jet Propulsion Laboratory are the individuals who serve on source selection boards and decide who wins or loses contracts and grants. If you are able to gain their long-term interest in your project—to develop relationships that allow you to talk and work with them, to learn their opinions and the directions they’re heading in to reach their goals—you have a great advantage. Government agencies and laboratories want to participate, to become more successful, and they can.”

George Gowgani: “I really appreciated your CASA presentation, but I first want to respond to a few of the comments that were made at an earlier session this morning. When we speak about California and about Cal Poly we have to remember that our complex state has the sixth largest economy in the world and a full range of both advantages and problems, and that Cal Poly is only one of the schools in the California State University system, which is the largest higher education system in the world. This morning we heard that approximately 400 engineering students with 4.0 high school GPAs were turned away from Cal Poly because of capacity constraints caused by a lack of funding. Some of us in the audience were already aware of this fact, but others were not and expressed their disappointment. It needs to be remembered that of the 23 campuses within the state university system, only Cal Poly and three other campuses are impacted in terms of their enrollments. Cal Poly cannot possibly admit every excellent student who applies—the other campuses offer good programs that deserve to be funded, even if those programs don’t attract a full enrollment.

“We’ve been talking about California’s financial crisis and the problems a shortfall creates, especially when so many different programs need money, and so much of the state’s budget is earmarked, which further limits any flexibility in making funding decisions. At the 23 state university campuses that I visit I find the same money dilemma and my response at each school is always the same—neither California nor any other state can continue to provide its universities with the necessary resources. The situation is even worse elsewhere—the University of Michigan no longer considers itself a state-supported school, but instead ‘state-affiliated,’ because the government’s contribution is so small. All the other states confront similar funding problems.

“So, after years of experience at every level in our state university system, I am delighted to hear what CASA has done and believe that the CASA partnership is a model for the future. The programs at our universities need to follow the example set by the CASA project if they are to thrive instead of being left behind. I was very impressed by the description of how CASA works. Your strategies might not apply to agriculture programs—agriculture has its own ways of doing things—but I am delighted at CASA’s example of forming partnerships to raise resources and accomplish goals that include the support of university education.”

Russell: “Thank you very much.”

William Swanson: “I just wanted to comment on the potential for industry collaboration around agricultural problems and issues. Mark Russell is currently working on a project to develop technology to eliminate the spongy portions of frost-damaged fruit, a program that might
offer a great collaborative opportunity for California universities and farming interests. We have engineers who are looking for problems that need to be solved and there might be a way to make a collaborative effort with Cal Poly because of your learn-by-doing philosophy and systems engineering capability. Partners in worthwhile and successful partnerships ask themselves, “What problem can we all put all of our energy into solving, so that people will benefit?”

Russell: “Partnerships need a central vision to rally around, an important problem that partners can work together to solve. If you can clearly define a problem that matters to people, you can gather partners to find a solution in a mutual effort that strengthens each member of the partnership. The CASA project has resulted in added resources for the University of Massachusetts, in more laboratories and facilities for undergraduates, because students are now doing research on antennas and software and working on Raytheon’s contracts.

“Again, the need to solve a problem forms the center of the partnership. If you can define an agricultural problem, you will find universities and companies and government agencies willing to join in your partnership. Government is eager to work with both the university and industry to find answers for problems that will improve the lives of Americans.

“Here at Cal Poly, I think you need to identify a pressing problem, so that people can enthusiastically join together and pursue a common vision. The problem waiting for a solution might involve agriculture, or something in the local economy. I do believe that it’s the team, partners working together, that makes the breakthroughs and always prevails. Teamwork always beats talent, as any coach will tell you. If you have a good team—government, industry and academia—you are going to win.”

Fox: “I’d like to close with a comment about integrating partnerships into the university culture, a point that Mark succinctly makes when he points out that partnerships create many winners. For universities, partnering means that funding comes from industry and from federal agencies and that important academic and research projects are no longer solely dependent on state budgeting processes. Students, society and everybody win.

“CASA began as a small partnership and grew in size and scale. I’m sure that there are many partnerships that can be developed by California universities—a single institution can manage one or two projects involving tens or hundreds of millions of dollars and at the same time, using a similar partnership framework, form many smaller, valuable partnerships that benefit each partner and our society.”
I would like to first thank the members of the Cal Poly President’s Cabinet for conceiving the idea of a biennial forum devoted to important contemporary issues that concern our society and its educational systems. The forums and their published reports have provided a significant resource for Cal Poly’s strategic planning. In these closing remarks, I will offer a few observations and examples that illustrate the growing importance of university/industry/government partnerships to our campus, as we consider what it means to be a polytechnic university in the 21st century.

Our first two forums, which dealt with the STEM pipeline, resulted (at the cabinet’s recommendation) in establishment of Cal Poly’s Center for Excellence in Science and Math Education. As we developed this center, we found that partnerships with national laboratories in California offered novel opportunities to advance the recruitment, preparation, retention and professional development of science and math teachers. Cal Poly has embarked upon a formal alliance with California-based Department of Energy and NASA research labs, initiating STAR (Science Teacher and Researcher), a start-up program that provides summer research internships for aspiring and early career teachers in five Bay Area federal labs. Teachers who participate in this program are able to communicate the excitement and insights gained from their applied research experiences to students in their K-12 classrooms. STAR offers continuing opportunities for teachers to connect with and stay connected with the broader scientific community, and promotes teacher recruitment, renewal and retention. STAR is a great example of how, through external partnerships, we can better achieve educational goals and ultimately meet the needs of society for creative STEM teachers and students and skilled high-tech professionals.

The demands of the diverse and highly competitive 21st-century global workplace require that Cal Poly continuously review and update its curriculum and provide an educational experience that prepares students in all disciplines to deal with rapidly changing contemporary realities. A deep immersion in a single academic area of study is no longer sufficient to equip graduates to succeed and contribute in the business and industrial environments and in the new world community outside the university. Real-world projects, especially those developed in partnership with industry, provide excellent opportunities for students to see how the methods and expertise of different disciplines are brought to bear to solve problems.

Through partnerships with government and industry, faculty from multiple disciplines also have opportunities to come together to conduct applied research that addresses important technical and societal challenges. Finding research solutions to real, in-context social, economic, environmental and technical problems requires the ability to identify and
address multiple factors, influences and ramifications. The CSU Agricultural Research Initiative (ARI) is an excellent example of programs that support this kind of professional experience. Funded jointly by industry and government, ARI permits faculty to bring applied research to bear on problems that range from water delivery to urban/agriculture interface concerns.

We have also found partnerships to be of inestimable value to our efforts to generate institutional resources. On one hand, we find that our efforts to garner public support for programs and facilities are enhanced by our ability to attract private support. Similarly, it is easier to attract private funds when we are able to demonstrate public sector support. Public/private funding strategies will play an increasingly prominent role going forward, because we know that we can no longer expect the state of California to support the university at previous levels. Cal Poly once received nearly 100 percent of its monies from the state, but today that amount is closer to 60 percent, and the percentage will continue to decrease—not necessarily because state funding will fall, but because we will aggressively continue to gain more of our support from other sources.

I believe that this year’s forum has provided us with a tremendous resource for thought and planning as we work hard to ensure that Cal Poly’s education and research programs keep pace with the demands of a rapidly changing world. A myriad of challenges, including issues of climate change, sustainability, human diversity and equality, and globalization require that we work together as a team within the university, across disciplines—to prepare graduates well-equipped to succeed in this new century and for Cal Poly to meet its obligations as a public, polytechnic university.
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