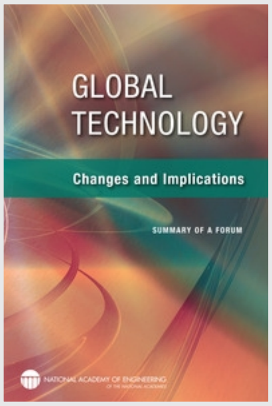

Global Technology: Changes and Implications: Summary of a Forum

DETAILS

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GLOBAL TECHNOLOGY

Changes and Implications

SUMMARY OF A FORUM

Prepared by Steve Olson
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Advisers to the Nation on Science, Engineering, and Medicine

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Preface

Engineers know what they mean by the word *technology*. They mean the things engineers conceive, design, build, and deploy. But what does the word *global* in the phrase *global technology* mean? Does it mean finding a way to feed, clothe, house, and otherwise serve the 9 billion people who will soon live on the planet? Does it mean competing with companies around the world to build and sell products and services? On a more immediate and practical level, can the rise of global technology be expected to create or destroy U.S. jobs?

A fascinating three-hour forum exploring these and related questions was held at the annual meeting of the National Academy of Engineering on October 4, 2010. The format of the forum was both simple and effective: we brought together seven extremely smart people and let them talk. Each brought a fascinating and unique perspective to the topic.

Esko Aho, executive vice president of corporate relations and responsibility at Nokia, spoke about the necessary ingredients that enable countries to be successful in an interconnected and technologically sophisticated world. Esko, who became prime minister of Finland when he was just 37 years old, deserves substantial credit for helping to make Finland a high-tech powerhouse.

Bernard Amadei, professor of civil engineering at the University of Colorado, discussed the responsibility of engineers to address the needs of all people in the world, not just those in the richest countries. Bernard is the founder of Engineers Without Borders-USA and Engineers Without Borders-International, a network of engineers from around the world who share knowledge and solve problems. These organizations have inspired many thousands of young people worldwide to share

NAE President Charles M. Vest and forum panelists.

their knowledge and talents with people in less developed countries to improve their quality of life.

John Seely Brown, visiting scholar and advisor to the provost at the University of Southern California and for nearly two decades the director of the Xerox Corporation's legendary Palo Alto Research Center, talked about how young people are changing the world through their use of technology. John—or JSB, as he is often called—has given himself the title "Chief of Confusion," yet his remarks were anything but confusing. He provided remarkable insights into what it will mean to live in a world where people are linked together and doing things in ways that were previously unimagined.

Ruth David, president and chief executive officer of Analytic Services Inc. and a former deputy director for science and technology at the Central Intelligence Agency, analyzed the rapid recent expansion of the scientific and engineering research workforce around the world. The United States still leads in many measures of science and technology expertise and productivity, but other countries are narrowing the gap, which creates both challenges and opportunities for the United States.

Eric Haseltine, a consultant in management and innovation and for many years a leader of Disney Imagineering, discussed engineering in a world where the boundaries of space and time are disappearing. The former associate director for science and technology in the Office of the Director of National Intelligence, Eric has an ideal background for observing global trends in science and technology.

Nicholas Negroponte, who with Jerome Wiesner co-founded the famous Media Lab at Massachusetts Institute of Technology (MIT), described his work with the One Laptop per Child Association Inc. The idea is deceptively simple: What if every child in the world had an inexpensive low-power laptop connected to the Web? The foundation has already distributed an astounding number of laptops in countries around the world, and in the process it is changing how people think about education and about society.

Raymond Stata, cofounder and chairman of the board of Analog Devices Inc. and a quintessential American technology-based entrepreneur, focused on the coming era of systems engineering. Ray came to the United States to study at MIT, stayed in the country to work, and cofounded what has become a globally successful company. When that company was challenged by foreign competitors, he rolled up his sleeves, spent innumerable hours studying the new world of quality management, and emerged with a company that was even stronger than before.

At the end of the forum, I conducted a simple poll of the seven panelists by asking them if globalization of technology is a good thing or a bad thing. Without hesitation, all responded that it is a good thing. The spread of technology throughout the world will bring hope and prosperity, but it will also increase complexity and risk. The global challenges for adequate water, food, health, energy, security, and a livable climate cannot be overcome by technology alone. But neither can any of them be overcome without technology.

Charles M. Vest, president
National Academy of Engineering

Contents

1

Perspectives on Global Technology

In the first half of the forum, each panelist explored a specific dimension of the global spread of technology. The topics varied widely—from reducing poverty to the impact of young people on technology to the need for systems thinking in engineering. But all seven presenters foresaw a world in which engineering will be fundamentally different from what it has been.

ENGINEERING FOR THE OTHER 90 PERCENT

Many people on Earth are living longer and better lives than ever before because of engineering. Life expectancy in the United States a century ago was 47 years. Now it is about 77 years, largely because of improvements in sanitation, food and water quality, health care, and other technological systems designed at least in part by engineers.

But the engineering profession has focused largely on the needs of a relatively small percentage of people, said Bernard Amadei, professor of civil engineering at the University of Colorado and founder of Engineers Without Borders. Life expectancy in Zambia is only about 32.5 years. Eighteen countries in the world still have a life expectancy of less than 50 years, and 79 have a life expectancy of less than 70 years. On an average day, 5,000 people die from indoor air pollution; 5,000 to 10,000 die from inadequate sanitation; 5,000 die from malaria; and comparable numbers die from tuberculosis and HIV infection. Altogether, Amadei said, 25,000 to 75,000 people die every day from causes that are clearly preventable, or as many as 200,000 people per week. That number is comparable to the death toll from the Haiti earthquake—week after week, month after month, year after year.

Bernard Amadei, founder of Engineers Without Borders and professor of civil engineering at the University of Colorado at Boulder.

Amadei founded Engineers Without Borders to address the needs of people who work simply to stay alive by the end of the day. The organization now has some 12,000 U.S. members, about half of whom are working in 48 different countries. There are 400 chapters in the United States alone, some consisting largely of students, others of professionals.

Amadei cited three particular challenges for engineering. The first is engineering in an emergency. What does engineering look like two hours after an earthquake, a week after an earthquake, eight months after an earthquake? How do engineers make the transition from rapid response to recovery to development to sustainable development? Engineers tend not to be in the field after emergencies, despite the contributions they can make to recovery, sanitation, education, and policy. "I was in Haiti in March. Not a pretty picture. There were 1.6 million people in the streets of Haiti in March. They are still in the streets of Haiti."

A second challenge is engineering in native cultures. Engineering does not necessarily look the same in developing parts of the world as it does in the developed world. Amadei described an example of what he called frugal engineering—an engineer in India who devised a solar-powered electrocardiographic device that costs $800 and can generate an electrocardiogram for about a dollar. "Eight hundred dollars is pretty much what I would pay if I would go to Kaiser Permanente for one EKG in the United States. Here is an example of frugal engineering. Your market is 5 billion people."

> Engineering in emergencies, engineering in native cultures, and engineering in extreme or very difficult conditions—have in many ways not yet been invented. "There is a huge environment for innovation, but we need to change our mindset."
>
> *Bernard Amadei*

Finally, Amadei described the challenge of engineering in difficult conditions. Recently he was working in Peru at an elevation of 14,000 to 15,000 feet. "Try to find water at 14,000 feet. Try to find energy at 14,000 feet. And yet people live in these very difficult conditions."

These three areas of engineering—engineering in emergencies, engineering in native cultures, and engineering in difficult conditions—have in many ways not yet been invented. But tremendous progress could be made in each, especially if the efforts of engineers were complemented by those of doctors, dentists, nurses, teachers, and other professionals. "There is a huge environment for innovation," he said, "but we need to change our mindset."

GLOBAL EXPANSION OF THE RESEARCH WORKFORCE

In recent years, there has been a major global increase in the number of people engaged in scientific and technological research. According to the 2010 *Science and Technology Indicators*, the research workforce in the United States and Europe grew by about 35 percent. In China and several other countries, the research workforce doubled.[1]

Three factors have contributed to the rapid expansion of the scientific and technological workforce, said Ruth David, president and chief executive officer of Analytic Services Inc. First, greater access to information through digital technologies has enabled people all over the world to build more rapidly on the collective knowledge of the science and engineering communities. Second, greater access to people has made it possible to forge networks and collaborations without regard to

[1] National Science Board. 2010. *Science and Technology Indicators 2010*. Arlington, Va.: National Science Foundation.

Ruth A. David, president and CEO, Analytic Services Inc.

geographic boundaries. Third, greater access to computing has put the power of supercomputers on a desktop, and the advent of cloud computing promises even greater capabilities.

The United States still has the lead in several indicators of research productivity, but the trend lines are raising concerns, said David. In 2008, for the first time, more than half of the patents granted by the U.S. Patent and Trade Office were awarded to companies outside the United States. Surveys conducted routinely by the National Venture Capital Association indicate that venture capitalists intend to increase investment IN Asia and other areas and perhaps reduce venture capital investments in the United States. "You can argue that the baseline still isn't bad. We have a robust VC investment community. But again, I think it is important to look at the trends."

> In 2008, for the first time, more than half of new U.S. patents were awarded to companies outside the United States.
> *Ruth David*

A recent National Research Council survey of six nations—Brazil, China, India, Japan, Russia, and Singapore—found that these nations are generally pursuing a two-pronged strategy in science and technology.[2] One part of their strategy is to focus on areas where science and technology can address particular needs in their respective countries. The other part is to build their economies in the global marketplace, thereby capturing a greater share of the benefits of scientific and technological advances. Most sobering, according to David, is a 50-year road map for science and technology published by the Chinese

[2] National Research Council. 2010. *S&T Strategies of Six Countries: Implications for the United States*. Washington, D.C.: National Academies Press.

Academy of Sciences. "Having been captive inside the Beltway for a few too many years, it is hard to plan 50 days ahead, let alone 50 years."

Wisdom, expertise, and talent are everywhere and cannot be confined by national borders. The transnational nature of science and technology creates a delicate balance of challenges and opportunities for the United States. For example, businesses increasingly view cross-border exchanges as collaborative opportunities, not just as competitive threats. Although U.S. universities in the past have relied on foreign students coming to the United States to study, today they have international collaborations, international campuses, or both. Similarly, U.S. industries today have both manufacturing plants and research facilities abroad. The world may not yet be flat, said David, but it is certainly flattening.

THE GLOBAL YOUTH MOVEMENT IN TECHNOLOGY

In past generations, people tended to create their identities from what they wore, what they owned, or what they controlled, said John Seely Brown, a visiting scholar and advisor to the provost at the University of Southern California. Today's young people increasingly forge their identities from what they create and what they share. "This is a very positive fact," said Brown. It helps to explain the do-it-yourself (DIY) and do-it-together (DIT) movements that are sweeping across the world. It also influences how people think about and use technology, no matter what their age.

Brown described four aspects of the global youth movement in technology. The first is the open-source movement, which extols the virtue of producing software and other goods and making them freely available. More than half the web sites in the world are running the open-source programs Linux and Apache, said Brown. One day shortly before the forum he logged onto an open-source site and saw that in a single day the site had provided 2.8 million downloads of computer code, had uploaded 4,200 contributions of code, had posted 1,200 forum entries, and had tracked 576 programming bugs. "This is a worldwide movement," he said.

Brown said that when he was an undergraduate he became well known for writing code that more or less worked, but no one could figure out how it worked. "That doesn't cut it today," he said. "It's the other way around." Young people write code today so that it can be read and improved by others. In doing so, they build social capital and personal reputations. In this way, the open-source movement has become

John Seely Brown, visiting scholar and advisor to the Provost at University of Southern California and the independent co-chairman of the Deloitte Center for the Edge.

a new mechanism for creating and expanding technology.

The second phenomenon Brown discussed is the union of amateurs and professionals. The world *amateur* comes from the Latin *amare*, meaning to love, and amateurs are applying their love of particular topics in professional settings. For example, a simple $3,000 Dobsonian telescope, when combined with a charge-coupled device sensor, has power equivalent to the 200-inch telescope at the Palomar Observatory in California when it began operating in 1949. Furthermore, small telescopes around the world are now networked, and amateurs are watching the sky 24 hours a day and making new discoveries. As an example, Brown cited the 2-meter Faulkes telescope on Maui that can be accessed through the Internet by schoolchildren, museums, and amateurs. He also mentioned the rediscovery by two schoolchildren of an asteroid that had been previously tracked and lost. “Those two kids are scientists for life,” he said. “The joy of finding something like that and getting national, if not international, recognition for it was really tremendous.”

The third trend Brown cited is a return to making things. Events such as Maker Faires (*http://makerfaire.com/*) and facilities such as Fab Labs (*http://fab.cba.mit.edu/*) are engaging students in the design and construction of technologies. “You learn by being tinkerers,” said Brown. “Most of us in this room probably grew up that way.”

Finally, Brown discussed engagement in imaginative worlds made possible by technologies. Children who have become fans of the Harry Potter books do not just read them. They contribute to fan sites, construct mythical worlds, and fill in the back stories of characters. On one site, 386,000 stories have been archived. Global discussion groups have children reading and writing outside of school in ways that were not possible before. Similarly, massive multiplayer games like World of Warcraft bring together millions of participants to create new and imaginary worlds. When Brown recently logged onto a World of Warcraft site, 15,000 new ideas had been posted in a single day. "These kids are producing knowledge amazingly fast," he said. "You might think [this is] for fun or for wasting time. But these kids are creating ideas and learning from each other at blinding speed that is very much mimicking the speed at which knowledge is being created in the scientific community. They are used to constantly absorbing and adding back to that knowledge on a day-by-day basis."

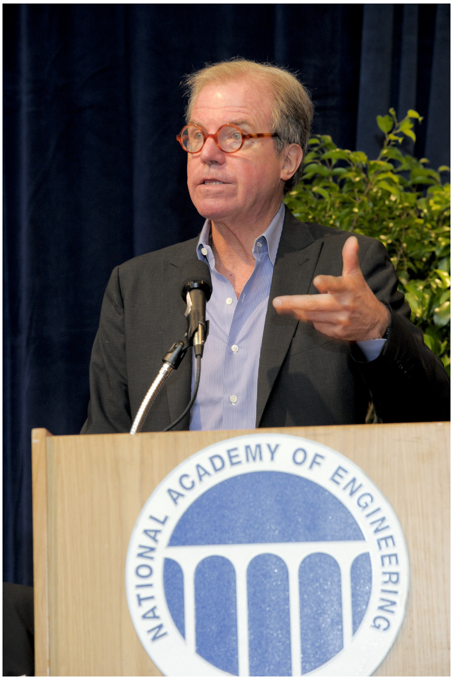
" . . .kids are creating ideas and learning from each other at blinding speed that is very much mimicking the speed at which knowledge is being created in the scientific community."
John Seely Brown

THE ONE LAPTOP PER CHILD REVOLUTION

Of the approximately 1.2 billion children in the world, half live in poverty, and 100 million do not go to school at all. "I don't mean they drop out of school at some point," said Nicholas Negroponte, founder of the One Laptop per Child Association Inc. and founder and chairman emeritus of the Media Lab at Massachusetts Institute of Technology. "A hundred million don't go to first grade." Adding underserved children who are not counted in this statistic could double that number.

One way to counter the tremendous education gap in the world is to build schools and train teachers, and this clearly needs to be done. The One Laptop per Child project takes a complementary approach. It has designed a very low-cost, low-power, interconnected laptop and has distributed these laptops in large numbers to children. This approach is based on five principles:

1. The laptops are designed to be owned and used by children.
2. Laptops are geared for children aged 6 to 12, although they can also be used by younger or older children.
3. Every child and teacher in a given region should have a laptop.
4. Laptops are designed to provide an engaging wireless network.
5. Laptops should be able to use free and open-source software tools.



Nicholas Negroponte, founder and chairman of the One Laptop per Child nonprofit organization.

Uruguay is the first country to have achieved digital saturation. Every child in the country aged 5 to 15 has a laptop with an e-mail address, and WiFi connectivity is widespread. "The transformation is extraordinary," said Negroponte. "The children are teaching their parents how to read and write. Older kids are teaching their younger siblings. There is anecdote after anecdote."

Providing a laptop for every child changes the nature of teaching. In places like the city of Gaza, where the foundation has also been working, teaching had been very rigid, with children lined up in perfect lines and afraid to ask questions in case they might be wrong. With laptops, the children can exert responsibility over their own learning. Truancy rates that were 20 to 30 percent have dropped effectively to zero.

The idea of one laptop per child is not new, said Negroponte. When he was working in Cambodia in the early 1980s, the laptops children took home at night were often the brightest light source in the village. Some of the earliest laptops designed for wide distribution in the developing world were built with a crank on the side to provide power. Although the crank proved to be impractical, "a lot of people remember it, and I still today meet people who say, 'Where's the crank?' because everybody remembers the pencil-yellow crank."

> "The children [with laptops] are teaching their parents how to read and write. Older kids are teaching their younger siblings. There is anecdote after anecdote."
> *Nicholas Negroponte*

These laptops connected remote villages to the world. If each of 100 interconnected laptops contained

100 different books, a village could have immediate access to 10,000 books, more books than most elementary school libraries have. Furthermore, the laptops can be connected outside the village to millions of books.

Private enterprise can provide some of these resources, but not all. "When I wake up in the morning, I ask myself one question," said Negroponte. "Will normal market forces do [what I'm doing today]? If the answer is yes, then stop. So everything we have done and everything we plan to do is what normal market forces will not do."

THE COMING ERA OF SYSTEMS THINKING

The U.S. semiconductor industry has captured more than half of the $250 billion worldwide market and exports more than 80 percent of what it produces, making it the number one exporting industry in America over the past five years. Moreover, the semiconductor industry enables a $1.5 trillion electronics industry that has been transforming daily life. "The success of the semiconductor industry has been a remarkable achievement by many different measures," said Ray Stata, cofounder and chairman of the board of Analog Devices Inc.

One of the most important factors behind the success of the semiconductor industry has been the preeminence of U.S. research universities. These universities nurture not just technical discoveries that drive innovation and growth but also the technical workforce that has made the semiconductor industry a success.

Even though for many decades the United States has not generated enough American-born engineers to meet the requirements of the U.S. engineering workforce, research universities have attracted the best and brightest students from around the world to study in the United States, especially at the graduate level. Moreover, many of these engineering students remain in the United States to work and make essential contributions to U.S. companies. Although existing statistics are uncertain, at least 70 percent of foreign students, and possibly as many as 90 percent, are still in the United States five years after graduation. "There is no way that we would have been able to achieve the things that we have in our company and in our industry without the contributions of these foreign-born engineers," said Stata.

Of course, the success of the semiconductor industry is due to other factors as well. In particular, large and small companies play an essential role in the continuing development of the technical workforce and in commercializing new technologies created in universities and industry.

At least in the semiconductor industry, said Stata, "entrepreneurs in America know how to create and commercialize technology better than in any other place in the world."

However, the semiconductor industry and universities both face momentous changes in the years ahead. Stata cited the late Wharton School professor Russell Ackoff, a pioneer in systems thinking, who said the performance of a system depends much more on how well the parts of the system work together than on how well they work separately. Yet the parts of universities still work largely in isolation rather than together. Universities historically have focused on excellence and innovation in individual academic disciplines, but the complex problems societies face today require the integration of disciplines. Universities must move beyond rewarding innovation and excellence within disciplines to optimizing innovation and excellence across disciplines.

The same observation can be made of industry. In the past, customers of the semiconductor industry typically bought components they could combine and integrate into their own systems. But customers today generally do not buy components and design their own systems. They want a supplier to take responsibility for integrating the parts and

Raymond S. Stata, chairman of the board and cofounder of Analog Devices Inc.

delivering them in the form of a complete systems solution. To accommodate this shift in demand, companies must recognize and reward the role of systems engineers.

This is not an either-or game, Stata observed. Innovation at the component level remains essential. But there are even greater opportunities for innovation in putting components together in unique and productive ways. "As we look to the future, that will become more important and will provide the opportunity for American industry and universities to stay ahead in the technology race."

> "Our role should be to move the goalposts, to continue to make American universities and industry more productive and the destination for the best and the brightest technical people from around the world."
> *Ray Stata*

Companies and universities in other countries are struggling to achieve parity with the United States in disciplinary excellence, and they are making tremendous progress. This is something "we should all celebrate and for which they should take great pride." Yet these institutions are far behind U.S. institutions in achieving excellence in interdisciplinary research and education. "It will take literally decades for them to build the depth and breadth of resources and experiences that it will take to compete broadly at the state of the art."

But the United States cannot stand still and wait for other countries to catch up, Stata insisted. "Our role should be to move the goalposts, to continue to make American universities and industry more productive and the destination for the best and the brightest technical people from around the world." Achieving this goal will require much greater attention to optimizing the performance of the whole as opposed to optimizing the performance of the parts.

This is a significant challenge to institutions that already consider themselves successful at what they do. But this transition is inevitable. U.S. companies and universities have an opportunity to lead this transformation. In doing so, they will help not only themselves but also institutions in other countries by demonstrating how systems thinking can improve the human condition.

Finally, said Stata, his experience indicates that a very small fraction of the engineering workforce produces the large majority of the breakthrough innovations in the world—the innovations that have the greatest influence on the progress of mankind. We need to find ways to identify and support this small fraction t to advance the frontiers of knowledge and capability.

The United States has a unique responsibility and opportunity to lead the way in thinking about how universities and companies will be different in the future. Systems-level thinking should be the guiding principle in moving forward.

ERASING THE BOUNDARIES OF SPACE AND TIME

In his former position as associate director for science and technology in the Office of the Director of National Intelligence, Eric Haseltine was responsible for coordinating the science and technology strategies of the national security agencies. Part of that job required tracking the development of science and technology in other countries. "It was a jaw-dropping, surprising experience," he said

One lesson he took away from that experience is that geography is dead. Technology development that used to happen exclusively in the United States and Europe can now happen anywhere in the world. "We no longer have the right of primacy in new technology."

> "... we can regain ... leadership by looking at this wave of change that's coming at us not as something that will drown us but as something we can surf to even more greatness."
>
> *Eric Haseltine*

Furthermore, the continuing acceleration of technology development has created new relationships between science, technology, and time. New phones or cameras used to be released every two years. Now they come out every six months. Google can issue a new software release every week. Open-source projects can receive thousands of software contributions every day. This acceleration is not simply a continuation of past trends, said Haseltine. At some point a quantitative change becomes qualitative, and "you're in a completely different universe without realizing it."

As an example, Haseltine described a recent request he received to develop a particular technology. He responded, not entirely truthfully, that the technology had already been developed. He then had one week to build and demonstrate a prototype. He quickly acquired components from Russia, East Germany, and China, downloaded open-source software from France to do image processing, and hired programmers in India. The final device had probably 200 million lines of code, Haseltine said, but it was ready and working in a week.

"The interesting thing is that once it was all done and I took a step back and looked at it, I said, 'Whoa, this thing is way different than I thought it was going to be.'" Combining the components in a particular way had produced capabilities much different from those of the individual components.

Eric C. Haseltine, consultant, former associate director for science and technology in the Office of the Director of National Intelligence, and former head of research and development at Disney Imagineering.

Haseltine dubbed this phenomena "the sex of ideas," a phrase coined by writer Matt Ridley. In a recent book, Ridley analyzed the sudden flowering of human culture 45,000 years ago when anatomically modern humans began to move out of Africa into the rest of the world.[3] Some scientists have posited that a genetic mutation flipped a switch in the human brain, leading to more sophisticated language and higher levels of human creativity. But a more plausible explanation is that changes in population density and social structure led to a sudden increase in the cross-pollination of ideas. "That is really what innovation is about today," said Haseltine. "That is what happened to me in this demo—I had created sex on my tabletop of ideas."

The greatest opportunity presented by globalization is another sudden increase in the cross-pollination of ideas. The result will be a tsunami of change as time and space are mashed together. "We can whine . . . about the fact that America is losing its leadership in engineering, or we can regain that leadership by looking at this wave of change that's coming at us not as something that will drown us but as something we can surf to even more greatness."

[3] Matt Ridley. 2010. *The Rational Optimist: How Prosperity Evolves*. New York: HarperCollins.

BECOMING A GLOBAL LEADER

When Esko Aho was born in 1954, Finland was a small, poor, politically and economically isolated, largely agrarian country. A half-century later, Finland is one of the most globally connected economies and societies in the world and has a leadership position in mobile technologies, forestry, sectors of the metal industry, and other businesses.

How did that happen, asked Aho, who was prime minister of Finland from 1991 to 1995 and is currently executive vice president of corporate relations and responsibility at Nokia. What were the ingredients necessary to make that transformation in just 50 years?

The first necessary ingredient, he said, is education for all. In Finland, the impetus for this came not just from government. In the 1950s and 1960s, the people of Finland, both rich and poor, embraced the idea that investing in education would be good for the country as well as for individuals. This conviction in turn placed great emphasis on the importance of good teachers. Today in Finland the nation's most talented and accomplished young people still want to become teachers.

Esko Aho, executive vice president, Corporate Relations and Responsibility, Nokia, and former prime minister of Finland.

The second necessary ingredient is substantial investment in research and development. In the late 1970s, when Finland was investing only about 1 percent of its gross domestic product in R&D—which was less than the average for the Organisation for Economoic Co-operation and Development (OECD) countries at that time—it decided to increase its R&D investments to 2 percent of GDP by 1990. It succeeded. And even during a severe financial crisis in the early 1990s when Aho was prime minister, R&D funding was increased by 80 percent.

The third necessary ingredient is an industrial ecosystem conducive to innovation. According to Aho, Finland has continually and substantially improved its innovative capacity since it began industrializing in the 1940s.

"A new generation of talented youngsters all over the world wants to see that we are able to do something good, and we have to be able to show that."
Esko Aho

The last necessary ingredient is the ability to take advantage of crises. Finland has had a number of internal and external crises in recent decades, which it has used in the way the United States used the Sputnik crisis to foment change.

Despite Finland's great success over the past 50 years, Aho is worried about the country's future. "We are too satisfied with our achievements and our capacity to make maximum use of our high-technology skills and talents," he said. More broadly, the European countries and the United States still have a huge technological capacity at their disposal, but other ingredients for success are not there. As an example, Aho cited the lack of incentives for developing uses for mobile technologies other than entertainment. "Why do we not use mobile technologies for education or for health care?"

The countries that will succeed in the future are those with the capacity to combine different types of talents to achieve global competitiveness, he said. Traditional approaches to R&D and education are no longer sufficient. Multidisciplinary training and teams will be essential.

Finally, Aho asked how young people can be convinced to study science and mathematics. Too many people believe that engineering creates problems rather than solves them. Companies must figure out how to get across the message that doing good business can be good for the world. "A new generation of talented youngsters all over the world wants to see that we are able to do something good, and we have to be able to show that."

2

Charting a Path into the Future

In the second half of the forum, the panelists discussed a variety of issues raised by moderator Charles Vest and by forum attendees.

STRATEGIES FOR INNOVATION

Vest began by asking the panelists whether countries and companies need explicit strategies for technology development, given the tremendous amount of largely spontaneous creativity that occurs today, often in areas where new technologies are not expected to exert a great influence.

Ruth David responded that countries and companies do need strategies and that these strategies must exist in multiple dimensions. Most important, nations need strategies to create ecosystems that allow innovation to flourish. According to a recent study by the Boston Consulting Group, the United States ranks eighth in the world in its environment for innovation, demonstrating the need for a national strategy to make the United States competitive with other nations.[1] In addition, said David, a national strategy needs an international component, because so many of the problems countries face today transcend geographic borders.

Esko Aho agreed that both national and private-sector strategies are needed. At Nokia, for example, the link from content providers to consumers is straightforward for entertainment. But for educational

[1] James P. Andrew, Emily Stover DeRocco, and Andrew Taylor. 2009. *The Innovation Imperative in Manufacturing: How the United States Can Restore Its Edge*. Boston: Boston Consulting Group.

services, health care services, or banking services, governments have to be involved to create the conditions for innovation.

Government involvement is also essential for the United States and European countries to compete with up-and-coming countries like China, Aho said. The capacity of the Chinese and Indian governments to create innovative environments is weaker than in the United States, but the United States and Europe are hampered by the fact that they do not have an explicit strategy to compete. "We don't have awareness of what to do and how to do it," he said. The United States and European countries can each have their own strategies, but there must also be an agreement to protect common interests.

Eric Haseltine said that the issue is less what the strategy is than who has the strategy. "I am very skeptical that anything the government could do or would do ever will make a difference," he said. The United States is undergoing a slow erosion of its preeminence in science and technology, in part because the nation does not perceive the current situation as a crisis. The launch of Sputnik in 1957 was a crisis that impelled America to act, but no Sputnik exists today.

The focus of a competitiveness strategy must be on the individual, Haseltine insisted. Both in government and industry, time horizons continue to shrink, and reward cycles are becoming shorter and shorter. So industry is concerned largely with the next quarter, while the intelligence community is focused on the next week because terrorists operate in real time. A vision for tomorrow must pay off for individuals today so that innovation makes both tomorrow and today better. Some of the most important technologies of the past several decades have had revolutionary long-term impacts while also paying off for shareholders in the present. "If there isn't a strategy that does that, we [will] have no success at all."

> "I am very skeptical that anything the government could do or would do ever will make a difference."
>
> *Eric Haseltine*

Ray Stata, in contrast, said that the United States has a "pretty good strategy, and it actually works pretty well." That strategy is based on the relationship between research universities, the federal government, and industry. "It works remarkably well," said Stata, "there's just not enough of it." Past federal investments have helped produce America's scientific and industrial success, and continued investments will be necessary for this success to continue. Universities also need the freedom to exercise their entrepreneurial judgment in taking on problems such as energy and health care. "It is a question of making that system work better and not allowing it to erode."

> Knowledge inevitably leaks into the rest of society, but "we don't regret that. This is one of the outputs that we should value."
>
> *Ray Stata*

In the private sector, companies realize they have to be represented in emerging countries, which pushes them to establish technical resources outside their boundaries to access talent and markets. Multi-national companies in turn have a tremendous influence on the diffusion of technology. Stata's company builds design centers in other countries and transfers knowledge to engineers working in those centers. This knowledge inevitably leaks into the rest of the society, but "we don't regret that," he said. "This is one of the outputs that we should value."

John Seely Brown suggested that the game may have changed in a fundamental sense. Strategies may have to focus more on institutional innovation than on technological innovation. "Are there fundamentally new types of institutions that we need to create?" For example, the open-source programs Linux and Apache both have constitutions outlining acceptable practices. These kinds of innovations, which are unknown to most people, may be necessary to create the kinds of ecosystems being discussed. The Media Lab was another institutional innovation in terms of its relationship with MIT and with industry.

China is currently turning to institutional innovation to counter a lack of venture capital money for startups, Brown pointed out. Companies form networks among startups centered on good ideas. These kinds of institutional innovations may be the key to future success. For example, universities may have to find new ways of working with the outside world.

Strategies are only as good as the mindset that creates them, said Bernard Amadei. People in the developed world have an obligation, not just an option, to address the needs of the 5 billion people whose lives are precarious. People and nations also have a self-interest in pursuing this obligation, because isolation tends to create insecurity and instability. "In fact, I am quite surprised that we have not had much instability in Haiti after the earthquake."

To change strategies, mindsets must be changed. For example, engineering projects that cross national boundaries are a powerful

> China is turning to institutional innovation to counter a lack of venture capital for startups.
> *John Seely Brown*

way to build international understanding. Yet young people in the United States are ill prepared by their educations to address needs at the global level. When Amadei has brought civil engineering students into the developing world and asked them to pour concrete, they have no idea how to make concrete, even if they have studied concrete design. "They all want to change the world, but they don't know how to do it." Education must eliminate the gap that exists today between what students are taught and the needs of the real world.

AVENUES OF COMMUNICATION

The benefits of openness and communication were a prominent theme of the panelists' responses. Amadei, for example, pointed out huge opportunities in thinking and communicating across borders. For example, he has been involved in a sewage project in East Jerusalem where Israeli and Palestinian engineers are working together. "These people have been taught because of politics to hate each other," he said. But "when it comes to solving wastewater and water issues, they talk to each other because they have something in common." Engineers can be peacemakers and make the world a better place by helping people find the interests they share, such as energy, water, and telecommunications.

Engineers Without Borders is not a charity, Amadei emphasized. It is not about giving away fish but about creating fishing industries that can empower people who have the ability to succeed. "People have a lot of talent," Amadei said. "I see more talent in some villages in Africa than I see at the University of Colorado to be frank with you: hands-on talent, skill-based talent, people who have lived through floods and droughts and difficult conditions, [people] who know the rules of the game. They know more about engineering than I do. They know how to survive."

> Engineers can be peacemakers and make the world a better place by helping people find the interests they share, such as energy, water, and telecommunications.
> *Bernard Amadei*

International development is a two-way street, Amadei said. The question is not only what the developed world can bring to the developing world, but also what the developing world can bring to the developed world. Engineers in India and China are coming up with frugal solutions to local problems. They know markets, and the markets are huge. They know how to package products and sell them to 3 billion people.

> The most important outcome of a project, regardless of its original goals, may be communication. . . ending isolation.
>
> *Nicholas Negroponte*

Negroponte observed that the most important outcome of a project, regardless of its original goals, may be communication. The One Laptop per Child program began with the goal of changing education, but the most important outcome of the project has been ending isolation. The combination of poverty and isolation is devastating, he said. It is critical for children to be exposed to multiple points of view. When he was working in Gaza, he was struck by the fact that none of the students there had ever met a Jew, even though Israel was just a few miles away.

Negroponte also pointed to the transformative power of communications technologies. It is not possible to ship 10,000 books to a village in Africa, but 10,000 books can be made available through 100 interconnected laptops. Just as the developing world taught the developed world that land lines are not necessary in a world of cell phones, the developing world can demonstrate the value and use of electronic publications. "This is a very interesting change, because the developing world is going to change it." In response to a question from a forum participant, Negroponte said that, because of the value of communications, he believes that scientific literature should be open and freely accessible anywhere in the world.

Stata observed that hundreds of millions of people are entering the middle class because of the creation of wealth by technology around the world. The involvement of these people in a global conversation could help solve global problems. Corporations too can be powerful instruments for change, he said. Much of the development of the workforce occurs in the private sector, and the corporate world is more responsive to the marketplace, to customers, and to social change than other institutions. "From that point of view, I am a bit more optimistic about where we are heading in terms of the impacts of globalization and the opportunities for cross-border collaboration."

The opposite of global is national, said Negroponte. He has lived in many countries over the course of his life and has always had multiple passports. "I look at nationalism as a disease, and as a consequence of that I don't think of competitiveness the same way other people might." For example, why is the United States more concerned about India than about Finland? The overriding focus on competitiveness can be destructive, Negroponte said. One reason MIT is such a powerful university is because it has so many students from other countries. Those students provide "different points of view that make the graduate programs and the research programs so strong."

INTEGRATING SOCIAL AND TECHNOLOGICAL SYSTEMS

Vest observed that the 14 Grand Challenges for Engineering established by NAE—which address energy, water, climate, and sustainability; improving the delivery of health care; increasing security against both natural and human threats; and expanding human capabilities and joy—all require the integration of social and technological systems. How can this integration be achieved in a world where societal understanding and political will are often lacking?

> "Until we get a lot better at integrating and understanding how human behavior plays into the solutions [to the Grand Challenges] . . . our progress will be limited."
>
> *Ruth David*

David pointed out that the Grand Challenges are "the mother of all systems problems." Humans are part of these systems, and the problems cannot be resolved by technology alone. "Until we get a lot better at integrating and understanding how human behavior plays into the solution[s] of these issues, our progress will be limited." Another complication with meeting the Grand Challenges is the existence of what David called the "legacy infrastructure"—technological systems already in place that reflect outdated thinking. In many cases, this infrastructure has to be replaced or altered, which may give an advantage to nations with less infrastructure that can leapfrog ahead of the United States.

Amadei observed that social issues are inevitably intertwined with engineering issues. To create a fishing industry, there have to be fish and water in a river. That raises issues of social and environmental justice. Fishermen have to be sure they can to go the river and that it will not be closed by insurgents. That is an issue of security. Fishermen need access to good technology, which is engineering. People need to know how to skin a fish and how to sell it, which means they have to be social entrepreneurs. Engineers need to help create fishing industries, not just technologies for fishing.

Universities generally are not set up to advance understanding of complex social-technological systems, observed Brown. Instead, solutions often trickle up from below rather than being imposed from above. For example, marginalized children in inner cities have amazing creativity if they are given enabling platforms. Two-way avenues of communication should be established to permit ideas from outside the United States to work their way into this country. "Americans don't see it. They hear about it, but they don't feel it."

Stata pointed out that institutional innovations can enhance the ability of universities to deal with complex social-technological problems. A model is provided by virtual centers of excellence that bring together people from multiple universities to work on a particular problem or issue. "You get better results. But also the people from universities get together. They learn to work together. They learn from each other." The obstacles to collaborative work are usually posed by institutional policies and structures, not by researchers, Stata said.

Haseltine pointed out the tremendous impact of movies, television, and video games on people's attitudes. For example, the television show CSI has led to a huge influx of people into forensic science because the show depicted technologists and scientists sympathetically rather than as geeks. "We can help ourselves by working more closely with the media, not on what we do, but on who we are," said Haseltine. "What audiences relate to is the human story of someone who is trying to accomplish something, encounters an obstacle, and through strength of character overcomes that obstacle. And everyone in this room wouldn't be here if they hadn't done that in life."

> Obstacles to collaboration are usually posed by institutional policies and structures, not by researchers.
>
> *Ray Stata*

BANDWIDTH AS A FACTOR IN COMPETITION

As an example of a particular technological need, one participant asked about bandwidth, pointing out that his daughter in the Colorado mountains can communicate with networks at 1.5 megabits a second, whereas a person in Tokyo or Taipei can access 100 megabits a second and soon will have access to speeds of 1 gigabit a second. Given the importance of access to adequate bandwidth in a nation's competitiveness, how can connectivity be broadened in the United States?

Governments do not fully understand why bandwidth is important, said Brown, although the new administration has begun to change that mindset. Governments think that increased bandwidth is appropriately used just for education, whereas what bandwidth really allows is for people to get together and create things they could not create on their own. The United States needs to reconceive what the broadband infrastructure can do, which will change the discourse. The current head of the Federal Communications Commission intends "to bring some of these changes about," Brown said.

Aho observed that infrastructure alone is not sufficient. There must also be content to send over that bandwidth. "You need content, business skills, and talent as well," and this is an area where the United States is strong.

Member participation in a group discussion.

CHANGING THE NATURE OF ENGINEERING

To achieve the far-reaching goals discussed at the forum, it may be necessary to make fundamental changes in the engineering profession, panelists and forum attendees said. Haseltine, for example, insisted that engineering is not what engineers think it is. Engineering is not about changing technologies. It is about changing human behaviors. New technologies can perish in the "valley of death" between the research lab and the marketplace because people will not change their behaviors. Therefore, engineers may have to focus on behaviors to develop a technology.

Ben Shneiderman of the University of Maryland observed that many university faculty are having trouble shifting their attention toward social-technological systems, in part because universities are still reluctant to consider collaboration a measure of academic achievement. As additional signs of this lack of commitment, the National Science Foundation has only $15 million in its budget for social computational systems, and NAE does not have a natural home for systems engineering or social media technologies.

Karl Pister of the University of California, Berkeley, pointed out that the National Research Council has a division devoted to the behavioral and social sciences, and NAE could do much more to collaborate with this division. Another option would be for NAE to abolish its 12 sections to encourage more cross-disciplinary work.

Another forum participant asked about the feasibility of engineering schools working with other parts of universities on multidisciplinary projects. David responded that when she was in graduate school the college of engineering worked with the medical center at Stanford. "That was one of the most rewarding sets of projects, because it gave you a very different perspective as an engineer on seeing what you were doing in practice. I applaud those kinds of collaborative efforts that cross disciplinary boundaries."

Brown said that at the University of Southern California he has helped develop a collaboration between the Annenberg School of Communication and Journalism, the cinema school, and the school of engineering. The greatest problems with such collaborations are raising and allocating revenues and ensuring that young faculty members can work toward tenure, which is why institutional innovation is so important.

Another participant noted that engineering education currently tends to be very narrow and that NAE could be a positive force for change in what engineers learn. Also, involving larger numbers of young people in NAE could have a beneficial effect on the profession.

WOMEN IN ENGINEERING

The panelists discussed the role of women in engineering, who could be instrumental in changing the nature of the profession. Amadei pointed out that 56 percent of the members of Engineers Without Borders are women. Engineers Without Borders emphasizes the compassionate aspect of engineering, he said, which may be why so many women are interested in the program. A traditional approach to engineering has been simply to try harder if brute force does not work. "Guess what? You are not going to attract too many young women into engineering with that kind of marketing strategy. It is time to change the discussion." The problems addressed by Engineers Without Borders reveal that "engineering has a human face. It is not engineering just for the sake of the technology. It brings the left brain and the right brain and also brings the heart into the equation."

David agreed that the closer engineering gets to the application of ideas, the more it will attract women. There are huge opportunities for getting closer to the impact of what engineers do. There also are opportunities for reaching out to girls at much younger ages and showing them role models and examples of the effects engineers have on the world.

Problems addressed by Engineers Without Borders reveal that "engineering has a human face. . . . It brings the left brain and the right brain and . . . the heart into the equation."

Bernard Amadei

Brown said that engineering is going to shift more toward a sense of design as a part of engineering, and "designers have no trouble attracting women into their professions." Infusing schools of engineering with the spirit of design from schools of architecture and other parts of universities could hasten this transition.

Vest noted that according to a survey of women with strong mathematics skills, 99 percent said they wanted to go into a field where they can make the world a better place. As a result, NAE has been investigating ways to highlight the impact engineers can have on the world.

THE GLOBAL ENGINEER

The changes cited and predicted by the presenters suggest a new role for engineers, one in which the increasing prominence of transnational problems and the globalization of technology will create a distinctly global perspective. But how can engineers learn to see beyond boundaries, a forum participant asked, when boundaries are so often used to divide rather than unite people?

Haseltine responded by saying that he had gone to hear Beethoven's Ninth Symphony in Washington, D.C., the week before. In the final movement of the symphony, hundreds of people were on stage all singing together. "It occurred to me that [we all have] different politics, different points of view, different neighborhoods, but music is borderless. [With the] people up on stage, what united them—and uniquely in Washington—was something of the heart, some passion."

As digital communications lower or eliminate boundaries of time and space, people can readily find others who share their passions, and this trend is just beginning. "We are not at the end of social networking," said Haseltine. "We are at the very beginning of it. Some of these social networks will help people find each other based on what connects them versus what separates them. I think that is one of the great and exciting things about cyberspace."

Brown agreed that passion can unite people across boundaries. The new Chicago public library has a huge digital media learning center where students from inner-city neighborhoods throughout Chicago gather to create things. "It is amazing if you go in there at 3:30 in the afternoon to see people from all the different neighborhoods, almost all marginalized kids by the way, coming there to actually do things. These creation spaces offer more to work with than does formal education."

> "I am optimistic . . . that new methods [will] create local, national, and global communities that will have their impact. . . . It [will take] time before we . . . see all these human and social impacts . . . [but] we have good reason to expect that many of them will be possible."
>
> *Esko Aho*

The coming changes in engineering are momentous, and the problems that must be solved are pressing. Yet change of this magnitude will take time even if it begins immediately, cautioned Aho. When Gutenberg's printing press first came to Europe, it was used exclusively to do old things in a new way—printing books that monks had been copying for hundreds of years. Only in the 16th century was the printing press used in new ways, helping to inaugurate religious and scientific revolutions. "I am optimistic," he said. "I believe that these new methods [will] create local, national, and global communities that will have their impact. But it is not coming overnight. We are just in the beginning." Bangladeshis now have a mobile device in their hands with the same computing capacity as the Apollo moon lander. "It takes time before we are going to see all these human and social impacts, [but] we have good reasons to expect that many of them will be possible."

Appendix A

Forum Agenda

Annual Meeting Forum
Global Technology: Change and Implications

Monday, October 4, 2010
9:30 am – 12:30 pm, Eastern Daylight Time
JW Marriott Hotel
Washington, D.C.

Technology that affects the lives of people in all economic conditions in all corners of the globe is conceived, developed, and produced in locations all over the world. The global spread of technology will bring hope and prosperity, but also complexity and risk. The 21st century global challenges of water, food, health, energy, climate, and security cannot be met by technology alone, but neither can they be met without science and engineering.

In this forum, the expert panel below will explore many facets of global technology and offer guidance on the opportunities and responsibilities of engineering leaders.

Welcome

Charles M. Vest, President, National Academy of Engineering

Forum Discussion

Forum Participants:

Esko Aho, Executive Vice President of Corporate Relations and Responsibility, Nokia; former Prime Minister of Finland

Bernard Amadei, Founder, Engineers Without Borders, Professor, University of Colorado

John Seely Brown, Visiting Professor, University of Southern California; self-proclaimed "Chief of Confusion," Former Chief Scientist of Xerox Corporation

Ruth A. David, President and CEO of Analytic Services, Inc.

Eric C. Haseltine, Consultant, former Associate Director for Science and Technology in the Office of the Director of National Intelligence, and former head of research and development at Disney Imagineering

Nicholas Negroponte, Founder, One Laptop Per Child Association Inc., Founder and Chairman Emeritus of the MIT Media Lab

Raymond S. Stata, Co-founder and Chairman of the Board, Analog Devices Inc.

Appendix B

Panelists' Biographies

ESKO AHO, executive vice president, Corporate Relations and Responsibility, Nokia, since 2008 (when he joined the company), is responsible for Nokia's government and public affairs, as well as the company's global policies related to sustainable development and social responsibility; he has been a member of the Group Executive Board since 2009. Before joining Nokia, Mr. Aho enjoyed a long and distinguished career in government service, culminating in his term as prime minister of Finland from 1991 to 1995. After the presidential campaign in 2000, he joined Harvard University as a lecturer. As a member of the Finnish Parliament, to which he was first elected in 1983, he served on several key committees. He also was a member of the Nordic Council and the Finnish delegation to the Council of Europe, vice chairman of Liberal International, chairman of the Finnish Ski Association, vice chairman of the Finnish Olympic Committee, and president of the Finnish Innovation Fund (SITRA). Currently, he is a member of the International Chamber of Commerce (ICC) World Council and vice chair of ICC Finland, as well as a board member of the Technology Academy Finland, a member of the board of Fortum Corporation, and vice chairman of the board of Technology Industries of Finland. Mr. Aho is an invited member of the Club de Madrid, an independent organization of former heads of state and government that works toward strengthening democracy, and the InterAction Council, an organization of former heads of state and government that addresses economic, political, and social problems. He holds a master's degree in social science from the University of Helsinki. In his spare time, he enjoys literature and golf.

BERNARD AMADEI, a professor of civil engineering at the University of Colorado (CU) at Boulder, is the faculty director of the Mortenson Center in Engineering for Developing Communities at CU Boulder and holds the Mortenson Endowed Chair in Global Engineering. Dr. Amadei is also the founding president of Engineers Without Borders–USA and co-founder of the Engineers Without Borders–International network. Among other distinctions, Dr. Amadei was the 2007 co-recipient of the Heinz Award for the Environment and the recipient of the 2008 ENR Award of Excellence. He was elected a member of the National Academy of Engineering in 2008, was recently elected a Senior Knight-Ashoka Fellow, and has received two honorary degrees. Dr. Amadei received his Ph.D. in 1982 from the University of California, Berkeley.

JOHN SEELY BROWN is a visiting scholar and advisor to the provost of the University of Southern California (USC) and the independent co-chairman of the Deloitte Center for the Edge. Prior to joining USC, he was chief scientist of Xerox Corporation and director of its Palo Alto Research Center (PARC)—a position he held for nearly two decades. Under his leadership, PARC expanded its corporate research to include organizational learning, knowledge management, complex adaptive systems, and nano/microelectromechanical systems (MEMS) technologies. He is also a co-founder of the Institute for Research on Learning. Dr. Brown, often called JSB, is a member of the American Academy of Arts and Sciences and the National Academy of Education, a fellow of the American Association for Artificial Intelligence and American Association for the Advancement of Science, and a trustee of the MacArthur Foundation. He serves on numerous public boards (Amazon, Corning, and Varian Medical Systems) and private boards of directors. He has published more than 100 papers in scientific journals, and in 2004 he was inducted into the Industry Hall of Fame. His current book, *The Power of Pull: How Small Moves, Smartly Made, Can Set Big Things in Motion* (Basic Books, 2010), was co-authored with John Hagel and Lang Davison, and an earlier book, *The Social Life of Information* (Harvard Business Press, 2000, 2nd ed. 2002), which he co-authored with Paul Duguid, has been translated into nine languages. *The Only Sustainable Edge: Why Business Strategy Depends on Productive Friction and Dynamic Specialization* (Harvard

Business Press, 2005), a book he co-authored with John Hagel, is about new forms of collaborative innovation. A forthcoming book, *The New Culture of Learning*, is co-authored with Professor Doug Thomas at USC. Dr. Brown received a B.A. from Brown University in 1962 in mathematics and physics and a Ph.D. from the University of Michigan in 1970 in computer and communication sciences. He has also been awarded five honorary degrees.

RUTH A. DAVID is president and chief executive officer of Analytic Services Inc. (ANSER), a nonprofit corporation that addresses national security, homeland security, and public safety issues. In 1999, she initiated a corporate focus on homeland security, and in 2001, she established the ANSER Institute for Homeland Security. Analytic Services now operates the Homeland Security Institute, a federally funded research and development (R&D) center sponsored by the U.S. Department of Homeland Security (DHS), in addition to the ANSER operating unit. Before assuming her current position in 1998, Dr. David was deputy director for science and technology at the Central Intelligence Agency (CIA). As technical advisor to the director of Central Intelligence, she was responsible for R&D and the deployment of technologies in support of all phases of intelligence operations. Prior to joining the CIA in 1995, she held several leadership positions at Sandia National Laboratories, where she began her professional career in 1975. A member of the National Academy of Engineering (NAE), Dr. David currently serves on the NAE Council as well as several committees of the National Research Council (NRC); she also chairs the NRC Standing Committee on Technology Insight—Gauge, Evaluate, and Review (TIGER) and the NRC Board on Global Science and Technology. She is a member of the Homeland Security Advisory Council, which was established to advise the President, and now advises the secretary of DHS. She also serves on the Defense Science Board, National Security Agency Advisory Board, Hertz Foundation Board, and Wichita State University Foundation National Advisory Committee and is a member of the Draper Corporation. Dr. David received a B.S. from Wichita State University (electrical engineering) and an M.S. and doctorate from Stanford University (also in electrical engineering). She is co-author of three technical reference books and has published numerous articles.

ERIC C. HASELTINE is a consultant, former associate director for science and technology in the Office of the Director of National Intelligence (essentially chief technology officer for the entire intelligence community), former head of research and development (R&D) at Disney Imagineering, and former designer of virtual-reality technology for flight simulation for Hughes Aircraft. An expert on managing innovation processes with experience in the defense, entertainment, and aircraft industries, Dr. Haseltine has helped many organizations with sales and profits that have plateaued to "harvest the future" by developing far-sighted technological solutions that deliver near-term value. Applying the principles he describes in his book, *Long Fuse, Big Bang: Achieving Long-Term Success Through Daily Victories* (Hyperion, 2010), he helps find opportunities that are often staring organizations in the face but are not recognized because of a natural tendency to filter out unexpected or unwanted information. Based on his experience as a Ph.D. neuroscientist and a senior executive in both industry and government, he not only shows them how to find opportunities hiding in the brain's "don't-expect-don't-want" blind spots, but also how to capture these opportunities once they have been identified. His consulting clients include Fortune 100 companies as well as large federal agencies. Dr. Haseltine is president and managing partner of Haseltine Partners LLC, is the owner of 15 patents in optics, special effects, and electronic media and the author of more than 100 publications in science and technical journals, on the web, and in *Discover* magazine.

NICHOLAS NEGROPONTE, founder and chairman of the One Laptop per Child Association Inc., a nonprofit organization, is currently on leave from the Massachusetts Institute of Technology (MIT). An MIT graduate and a member of the faculty since 1966, Dr. Negroponte was a pioneer in the field of computer-aided design, co-founder and director of the MIT Media Laboratory, which was conceived in 1980 and opened its doors in 1985, and the Jerome B. Wiesner Professor of Media Technology. He is also author of the 1995 best seller, *Being Digital* (Knopf), which has been translated into more than 40 languages. In the private sector, he sits on the board of directors for Motorola Inc. and is general partner in a venture capital firm that specializes in digital technologies for information and enter-

tainment. The firm has provided startup funds for more than 40 companies, including *Wired* magazine.

RAYMOND S. STATA co-founded Analog Devices Inc. (ADI) in 1965, was CEO and chairman until 1996, and is now chairman of the board. Initially, the company focused on high-performance operational amplifiers and other linear IC's, but the direction soon changed to data converters and later to digital signal processors. With sales of $2.5 billion, ADI is recognized for its leadership in the design and manufacture of analog and digital signal-processing semiconductors. Since stepping down as CEO, Mr. Stata has been an investor in and board member of early-stage technology-based new ventures, both personally and through Stata Venture Partners. The company and Mr. Stata have invested in more than 40 startup companies mostly in America, Israel, and India. A graduate of Massachusetts Institute of Technology (MIT), Mr. Stata holds a BSEE and MSEE. Until 2010, he was chairman of the Visiting Committee of the Department of Electrical Engineering and Computer Science, served on the board of the MIT Corporation, and was a member of its Executive Committee. He is also actively engaged in MIT's Venture Mentoring Service, which provides voluntary advice by MIT graduates who have been successful entrepreneurs to students and faculty who want to become entrepreneurs. Mr. Stata is a member of the National Academy of Engineering and American Academy of Arts and Sciences and a foreign fellow of the Indian National Academy of Engineering. He was the recipient of the IEEE Founders Medal in 2003.