

The Gathering Storm: Can the U.S. Preserve its Lead in Science & Technology?

by Alan S. Brown

The National Academies exist to provide advice on science policy by tapping the wisdom of nation's top scientists and engineers. The academies are well known for their studied—often laboriously and over several years—reports. Some have influenced legislation and funding. Many more have been relegated to the policy backburner.

Then there is *Rising Above the Gathering Storm*. Completed in only 10 weeks, *Rising Above the Gathering Storm* was conceived as a wake-up call for the nation. It warns that the U.S. could rapidly lose its edge in scientific and technological innovation to economic competitors, thus degrading America's standard of living, employment opportunities, and national security.

"I've written plenty of science policy reports nobody read," says Robert Richardson, a member of the 20-person committee that led the report and Cornell University vice provost for research. "This report got a response. Two-thirds of the Senate signed on to a bill to implement its recommendations, and President Bush included it in the State of the Union. There's now a chance to have a discussion about science policy for the first time in a decade."

Politics as Unusual

Its short gestation led some critics, such as Roger Pielke Jr., director of University of Colorado's center for science and technology policy research, to argue that such fast work led to lapses of logic. Richardson disagrees. "Having just 10 weeks kept us focused," he explains. "In longer studies, most people don't look at the material until a week or so before the next meeting anyway."

The makeup of the committee also broke from past practice. The National Academies ordinarily fill their panels with academic and industrial experts. The Committee on Prospering in the Global Economy of the 21st Century, on the other hand, was populated with top corporate CEOs with solid Republican credentials who could command the attention of the President and Congress.

Chairing the committee was Norman R. Augustine, *New Jersey Delta '57*, retired chairman of Lockheed Martin Corporation, the nation's top defense contractor. "He's the person who made it happen," says Richard Zare, a committee member and professor of chemistry at Stanford University. "He's smart, passionate, hard-working, and really connected with the administration. When these industrial giants with Republican backgrounds unite with university people, then something really happens."

Other business leaders on the committee included the chairmen of Intel Corporation, DuPont Company, and Exxon Mobil Corporation and the former chairman of Merck & Company, Inc. Another member, investor Peter O'Donnell Jr., whose charitable foundation funds grants to improve math education, served on the Foreign Intelligence Advisory Board under the first President Bush. Academics included the presidents of Texas A&M University, Rensselaer Polytechnic Institute, and Yale University (the President's *alma mater*) and the president-emeritus of the Massachusetts Institute of Technology.

Of course, the only way the committee could complete such a comprehensive report in so little time is for its members to start with similar assumptions about the challenges facing the United States. The situation, explains O'Donnell, is very different from the panic that followed the launch of the world's first satellite, *Sputnik*, by Russia in 1958. "That was an international event where we felt threatened," O'Donnell explains. "Everyone jumped to, Congress acted promptly, and we all went to work."

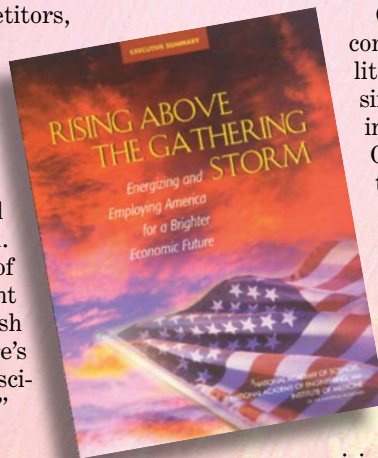
"The problem we're facing now is just what the title of the report says, a gathering storm. The threat is aimed at our jobs and our economic well-being. It's not arising in one place. It is coming from China, Japan, India, Hong Kong, and Singapore—countries focused on education and technology—who are creating products that are very good and cost less."

A Flat World

Those ideas crystallized in Congress after the publication of *The World is Flat* by *New York Times* Pulitzer-prize-winning-columnist Thomas Friedman in 2005. Its thesis may sound familiar to anyone on technology's front lines.

During the past decade, Friedman argues, the barriers to the free flow of information, technology, capital, and goods have fallen away. The Internet and vast investments in undersea fiber-optic cable have linked all but the most remote regions of the globe into a single, high-speed network. Anyone, anywhere can learn what other researchers, businesses, and governments are doing.

Driven by investments in education and economic liberalization, China, India, and other nations have transformed themselves rapidly into rising economic powerhouses. They have become both competitors and—thanks to software that enables business to share business and engineering data (such as CAD files and software code)—partners.



Many Americans thought they had heard this story before. Thirty-five years ago, the competitive threat was Japan. The first Japanese transistor radios—the foundation of the nation's long run in consumer electronics—sounded tinny. Toyota advertised its first vehicles in the United States as cute alternatives to the Volkswagen Beetle. Honda attempted to break into the U.S. market with a three-wheeled vehicle. Americans were shocked in the early 1970s to find that Japanese products surpassed the reliability of their American counterparts.

Several Pacific Rim nations, led by Taiwan, Singapore, and South Korea, adopted the Japanese model. They invested heavily in education. In the 1980s and 1990s, they shot up the quality curve, displacing Japanese products along the way. Today, Taiwan is a major supplier of computer electronics, while South Korea ranks among the leaders in memory chips and flat panel displays.

Differences

During the past decade, China and India joined the global economy with a jolt. China, in particular, has moved up the learning curve much faster than did the Japanese. Today, it exports computers, electronics, and telecommunications products to the United States while bringing back cotton, recycled newspaper (which it turns back into newsprint), and polymers.

While China and India are similar to other modernizing countries, they are also different. Sheer size sets China apart. Multinationals want to sell products to China's 1.3 billion citizens and its rapidly growing middle class that is already larger than the entire population of Germany. In addition to market potential, they also see low-cost labor that makes exports affordable.

The Chinese government demands that corporations pay admission to those markets. In exchange for building factories in China, foreign companies must take on Chinese partners, hire Chinese engineers, and bring in the latest technology.

As a result, more than half of the Chinese products sold in the United States come from factories owned or partially owned by Taiwanese, Japanese, and U.S. companies. Moreover, once those plants are up and running, their workers and technology begin to percolate through Chinese industry, thanks to the nation's notoriously lax intellectual property laws. Harnessing advanced technology to low wages and a thriving internal market enables even local Chinese companies to compete globally.

The Threat

Friedman's book energized two Senators, Republican Lamar Alexander of Tennessee and Democrat Jeff Bingaman of New Mexico. They asked the National Academies to define the top 10 actions and concrete strategies that federal policymakers could take to bolster America's science and technology establishment so it could compete and prosper in the global economy.

The resulting report, *Rising Above the Gathering Storm*, or RAGS, did not deliver a dry policy dissertation. Build-

ing on concerns raised by Friedman and other thinkers, it called for America to wake up. It started by highlighting a number of disturbing trends.

It stated, for example, that China graduated 600,000 engineers and India 350,000 engineers in 2004, compared with 70,000 in the United States. A U.S. firm that outsources work can hire 11 Indian engineers or five Chinese chemists for the cost of one similarly qualified U.S. professional.

RAGS also saw a problem with the pipeline. U.S. high school seniors performed below average on a general knowledge mathematics and science test administered in 21 countries. In a test of students taking precalculus, calculus, or advanced-placement calculus, 11 of 15 countries outperformed the United States and four scored similarly.

Equally disturbing, in 1999 only 41 percent of U.S. eighth-graders had a math teacher who either majored in mathematics or studied the subject for teacher certification. That was far lower than the international average of 71 percent.

The report notes that six of the top-10 corporate U.S. patent recipients are from other nations and that, by 2004, U.S. inflation-adjusted funding of physical sciences had fallen 45 percent from 1976. It also slyly noted that in 2001, U.S. industry spent more on tort litigation than on R&D.

To Congress, America's slipping lead in science and technology came as a shock. Both Republicans and Democrats embraced many RAGS recommendations to improve K-12 math and science education, fund more basic physical science research, help recruit scientists from around the world, and make innovation more business-friendly (see *RAGS Recommendations* at far right for details).

Yet some critics question whether the U.S. is losing its lead at all.

R&D Leadership

The University of Colorado's Pielke, for example, says that RAGS cites data that paints a rosy picture of America's basic and applied research capabilities. For example, U.S. researchers publish more scientific articles than anyone else does, and their names were listed on one-quarter of all scientific papers in 2004. Their papers are also cited more frequently as well.

A recent comparison found that the United States is home to 38 of the world's top 50 research institutions. It is the destination of choice for graduate and postdoctoral scholars from other nations. U.S. schools produce more than 20 percent of the world's doctorates in science and engineering. Many of those students stay here to create new products and businesses. Other graduate engineers from abroad also come to America to work.

In fact, the latest *World Competitiveness Yearbook* published by Swiss business school IMD International ranks the United States first in economic competitiveness, followed by Hong Kong and Singapore.

According to Pielke, federal R&D funding is not a good marker of commitment to research. During the past decade, he says, the federal government doubled the budget of the National Institutes of Health. Moreover, U.S. industry outspends the federal government on R&D by about 50

percent and increased spending by five percent to \$204 billion in 2003.

Yet Cornell's Richardson, who served on the RAGS committee, is not as sanguine. "The country's slipping fast," he warns. "For the past two years, American investors have been investing more in foreign corporations than our own companies.

"We think we're really advanced in broadband communications, but we rank 12th in the world in per-capita broadband connections. There's a growing gap in this country between the privileged and educated and the rest of the country.

"Our infrastructure—water, roads, bridges, railroads, the electrical grid—is wearing down. There are non-alarmist economists who say we will have to invest tens of trillions of dollars to keep it from falling apart. Where are the people who are going to do it? I'm not sure we're training them," he concludes.

Economics

The committee wanted to ensure the growth of high-paying technology jobs in the United States. RAGS points out that America's trade balance in technology products swung from plus \$54 billion in 1991 to negative \$50 billion in 2000. It also notes that low-wage employees like Wal-Mart and McDonalds created 44 percent of the new jobs, while high-wage employees created only 29 percent.

Those are the numbers. Their meaning lies in whom you ask. To David Hart, an associate professor at George Mason University's school of public policy, they mean that U.S. manufacturers have done what farmers did a century earlier. "There's still a lot of production here," he says. "There are just many fewer jobs because technology is replacing labor."

Moreover, the connection between increased funding for science research and new technology is not always clear. Many researchers question the "linear model" of technology development championed by U.S. science policy czar Vannevar Bush, *Massachusetts Beta '16*, after World War II. It assumes that countries wise enough to plow money into basic research will reap technologies that create new products and new industries.

To some extent, this has held true. Yet many U.S. advances in science—transistors, factory automation, and the integrated circuit—have helped offshore competitors as much or more than they aided U.S. companies.

Richardson admits that the coupling is not always obvious. Yet he also believes the nation benefits enormously from new scientific research that percolates through the entire engineering community. He asks, "Why does anyone go into science and engineering? Attorneys and M.B.A.s have higher incomes. But they do it because it's interesting and new."

Fresh ideas attract students to the field. As older industries fail, new ones are born. The U.S. may have lost its lead in cameras and transistors, but it retains it in creating lifelike visual animations and designing integrated circuits. New industries based on biomaterials and genetic engineering command enormous profits.

RAGS Recommendations

"Rising Above the Gathering Storm" made four major recommendations to retain America's competitiveness in science and mathematics. Each had several implementation actions:

Recommendation A. Increase America's talent pool by improving K-12 science and math education:

Give four-year, \$20,000/year scholarships to 10,000 math and science students in exchange for teaching K-12 for five years.

Offer a variety of programs to upgrade the skills of 250,000 existing teachers, and create a voluntary K-12 science and math curriculum.

Increase the number of students in advanced-math and science courses.

Recommendation B. Strengthen the nation's long-term commitment to basic research:

Double federal investment in long-term basic research over the next seven years.

Earmark \$500,000 in grants payable over five years to each of the nation's 200 top early-career researchers.

Set aside \$500 million annually over the next five years to fund new equipment for universities and governmental labs.

Allocate at least eight percent of existing federal research budgets for high-risk, high-payoff projects.

Create the Advanced Research Projects Agency-Energy (ARPA-E) with an eventually budget of \$1 billion to fund long-term energy research.

Create a Presidential Innovation Award to honor scientific and engineering advances in the national interest.

Recommendation C. Enhance America's ability to develop, recruit, and retain the best students, scientists, and engineers in the world:

Offer 25,000 new four-year undergraduate scholarships to increase the number of U.S. citizens who study science, engineering, and math.

Fund 5,000 graduate fellowships in areas of national need for U.S. citizens.

Provide tax credits for employees who fund continuing education for scientists and engineers.

Simplify visa processing for international students and scholars.

Automatically extend visas one year for students who receive doctorates so they can seek employment in the United States.

Give immigration preferences to those who have doctorates in science and engineering.

Reform the "deemed export" system to give foreign researchers in the U.S. better access to information and research equipment.

Recommendation D. Ensure that the U.S. remains the country for innovation:

Improve patent protection to encourage innovation and reduce litigation.

Boost tax credits to encourage greater investment in innovation.

Provide additional tax incentives for U.S.-based research and innovation.

Ensure ubiquitous broadband Internet access.

In grades five through eight, 69 percent of students are taught math by a teacher who did not major in math.

Yet no one can deny that today's flattened world makes it far easier for other nations to learn and apply scientific breakthroughs.

Education

When it was time for the 20 members on the RAGS committee to make recommendations, they started by ranking their priorities. "As a full committee, we voted on what was most important," recalls O'Donnell, whose charitable foundation funds development of AP math programs. "We decided K-12 education is our most important priority and the number one place to start is to strengthen our teacher corps.

"In grades five through eight, 69 percent of students are taught math by a teacher who did not major in math," O'Donnell continues. "In grades nine through 12, it's 31 percent. In physical sciences, those numbers are 93 percent and 53 percent. The point is, our teacher corps is not what we need. We need to strengthen it by recruiting and retaining teachers who understand science and math."

To do this, the report recommends a combination of scholarships, workshops, and part-time master's-degree programs. "We're going to have to start with teachers if we're going to create a pipeline of scientists and engineers," says O'Donnell.

Creating a pipeline of technically proficient students hardly seems controversial. Yet there is a flaw in the argument, says David Guston, associate director of Arizona State University's consortium for science, policy, & outcomes. "The report follows a long series of reports from the science community asking for more and more, with no other plan than to get more," he says. "Doubling the number of scientists and engineers is not a policy. What counts is whether we're training the right type of scientists and engineers."

According to Guston, the United States can never produce enough engineers to compete with China or India. "We have to compete based on the value of what they know," he explains. "For example, we need chemical engineers who know how to handle chemical byproducts in an environmentally sound way. They will be in greater demand than those who make things with polluting reactions. If we're not training our engineers to do this, then we're training the wrong type of engineers no matter how many we train."

George Mason's Hart says the math and science alone represent only part of what we need. "If we focus all our attention there, we're going to miss the interesting things that go on at the intersection of technology on one hand and arts and design on the other. I worry that the report might reinforce teaching to the test instead of encouraging more create inquiry."

A recent study by Gary Gereffi of Duke University questions whether developing countries even have an advantage in numbers. He finds most counts of graduating Chinese and Indian engineers include degrees in technology and computer sciences as well as those from two and three-year programs. After recalculating based on uniform criteria, he found the United States actually awards more four-year engineering oriented degrees than China and India combined.

Focus

Pielke questions whether we even need to prepare more engineers. Graduate schools typically fill about half of their slots with foreign students. Although some of those students return home, many remain in the United States, creating valuable intellectual property and starting new businesses.

"If we really had a shortage of scientists and engineers, then their pay would rise," he says. "That's classical economics, and it simply has not happened." RAGS, he notes, made several recommendations to make it easier for offshore students and professionals to emigrate and work here.

That may prove important because the United States now has to compete with other nations for scientific talent from around the world. "I knew it was serious when I heard that a French laboratory had changed its working language to English in order to attract Chinese and Indian researchers," says Kent Hughes with tongue only partially in cheek.

A former president of the Council on Competitiveness and director of the Woodrow Wilson Center's Project on Science, Technology, America, and the Global Economy, Hughes says the story underscores the dominance of the United States in technology. But it also means other nations are willing to do whatever it takes to develop their research capabilities.

Yet America's ability to draw professionals from around the world is not just based on our technological infrastructure. They come here, says Hughes, because we welcome them. "We're not just Americans because our great-grandparents were, but because we choose to live here," he says. "Individuals find it comfortable in the United States because they can become increasingly American without turning their backs on their own cultures. Fair play, diversity, law, our economy, the venture capital system—these are universal in nature."

Other nations, says Hughes, want to emulate that model to attract researchers from other lands. They are competing with us for talent. Although the United States will continue to attract skilled scientists, he would like us to develop more technically trained students.

For that to happen, the United States must stimulate demand, he says. "*Sputnik* created urgency about science and engineering, matched by an enormous flow of public and private funds into R&D," he recalls. "We had a goal that excited people. Now we should think about what kind of goal would excite young people today. Perhaps it might be the intersection of energy and the environment, or nanotechnology, or biotechnology."

Whatever that goal is, it must provide an immediate alarm because the storm that RAGS warns about is still gathering. It is hard to get the public and politicians to pay attention to a problem that is not an immediate threat.

Perhaps it is no real threat at all. After all, the United States has maintained its technical lead by tapping the best scientists and brightest engineers for decades. As long as we continue to do that, perhaps the United States will remain a leader—if not the only leader—in science and technology for the foreseeable future. *(Continued on page 44)*

The Gathering Storm

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The more fundamental question is whether every citizen of the United States will benefit from our leadership. Despite the decline in American manufacturing employment, educated professionals have done well the past decade or two. There is certainly reason to think, as economist David Ricardo wrote, that free trade between nations specializing in different products benefits both parties.

Yet in a flat world, the effects of unequal trade can roll across borders and flatten others. Their factories may not run as efficiently as those in the United States, Europe, or Japan, but cheap labor more than makes up the difference. Their professionals may not meet Western standards, but hiring 11 Indian engineers or five Chinese chemists for the cost of one similarly qualified U.S. professional probably bridges any gap in skills.

Eventually, as Ricardo said nearly 200 years ago, trade between nations will lift wages in India and China. Then their scientists, engineers, and workers will not have a cost advantage over their counterparts in developed nations. They will become a profitable market for U.S. products. Free trade will indeed benefit everyone.

Until then, it may be very uncomfortable. The cost advantages in well educated, highly motivated nations are going to cause changes in our business practices, our employment opportunities, and living standards.

Rising Above the Gathering Storm may not have all the answers. But it certainly has people talking about the problem.

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