

**Alabama Governor's Summit:
Mathematics, Science and Technology
Education**

Ross Bridge

March 6-7, 2006

Gail Cassell, Ph.D., D.Sc (hon.)

**Vice-President for Scientific Affairs and
Distinguished Lilly Research Scholar for
Infectious Disease**

Eli Lilly and Company

Indianapolis, IN

“Business and industry in Alabama—
as drivers of innovation and production, and
as employers—bring credibility, clout, and
leverage to mathematics and science
education reform efforts”

RISING ABOVE THE GATHERING STORM

*Energizing and
Employing America
for a Brighter
Economic Future*

NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, AND
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

**National Academies: National Academy of
Sciences, National Academy of Engineers,
and Institute of Medicine
(all honorific)**

*Chartered by Congress in 1863 to advise the
government on matters of science and technology*

FEBRUARY 13, 2006

TIME

FURY
OVER
MUHAMMAD

IS AMERICA FLUNKING SCIENCE?

Our superiority was once the envy of the world. But we are slacking off just as other countries are getting stronger. What's the formula for a comeback?

BY MICHAEL D. LEMONICK



www.time.com AOL Keyword: TIME

Committee

- Norman Augustine
(chair)*
- Craig Barrett*
- Gail Cassell
- Steven Chu**
- Robert Gates
- Nancy Grasmick
- Charles Holliday*
- Shirley Ann Jackson
- Anita Jones
- Joshua Lederberg**
- Richard Levin
- Dan Mote
- Cherry Murray
- Peter O'Donnell
- Lee Raymond*
- Robert Richardson**
- Roy Vagelos*
- Charles Vest
- George Whitesides
- Richard Zare

Charge to the Committee

Senators Alexander and Bingaman with endorsement of House Science committee requested National Academies to:

- Identify top actions federal policy makers could take so US can successfully compete, prosper, and be secure in the 21st Century
- Determine an implementation strategy with several concrete steps

Some Context

- Growing national concern about economy
 - Globalization
 - Out-sourcing & off-shoring
 - Rise of other nations
- Friedman: *The World is Flat*
 - 40+ weeks on the list of top selling books
 - Communicated the “message”

Method

- Review of literature, past reports, and suggestions led to 150 ideas
- Focus groups of experts discussed ideas and identified top 3-4 ideas in K-12 education, higher education, research, innovation and workforce, and homeland/national security
- Committee meeting and conference calls
- Additional expert consultations
- More than 40 anonymous reviewers
- 10 weeks from meeting to study release

Some Competitiveness Indicators

- The United States is today a net importer of *high-technology* products. Its trade balance in high-technology manufactured goods shifted from *plus* \$54 billion in 1990 to *negative* \$50 billion in 2001.
- Chemical companies closed 70 facilities in the United States in 2004 and tagged 40 more for shutdown. Of 120 chemical plants being built around the world with price tags of \$1 billion or more, one is in the United States and 50 are in China.
- In 2005, only four American companies ranked among the top 10 corporate recipients of patents granted by the *United States* Patent and Trademark Office.

Yet More Competitiveness Indicators

- In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore 67%. In the United States, the corresponding figure is 15%.
- Some 34% percent of doctoral degrees in natural sciences and 56% of engineering PhDs in the United States are awarded to foreign-born students.
- In the U.S. science and technology workforce in 2000, 38% of PhDs were foreign-born
- Federal funding of research in the physical sciences, as a percentage of GDP, was 45% less in FY 2004 than in FY 1976.

Findings

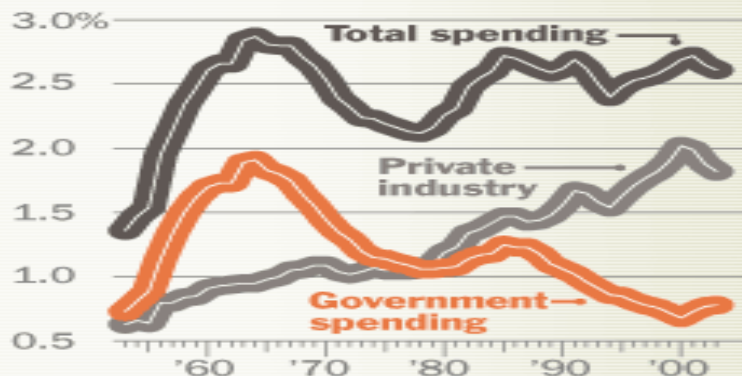
- Concern that the S&T building blocks critical to economic leadership are eroding when many other nations are gathering strength.
- “Death of Distance” means that skilled labor with strong drive to succeed is just a mouse-click away in growing economies and does not have to be in close proximity.
- Worldwide strengthening is good, but will the United States be able to compete when great minds and ideas exist throughout the world—at a lower cost—so greater return to investor.
- If do not have high-quality jobs, then do not have means for a high standard of living.
- Fear abruptness with which lead can be lost and challenging of recovering if lost.

SPENDING ON RESEARCH

The U.S. pours more money into science than does any other country, but federal funding — vital for basic research to develop new technologies — has been shriveling. Six countries now devote a larger share of their economy to science



U.S. spending on research and development as a percentage of GDP



Top 10 countries in research spending as a percentage of GDP*

Israel	4.43%
Sweden	3.98%
Finland	3.49%
Japan	3.15%
Iceland	3.04%
South Korea	2.64%
U.S.	2.61%
Switzerland	2.57%
Germany	2.55%
Denmark	2.53%

*2003 data, except Israel (2001), Switzerland (2000), and Denmark (2002)

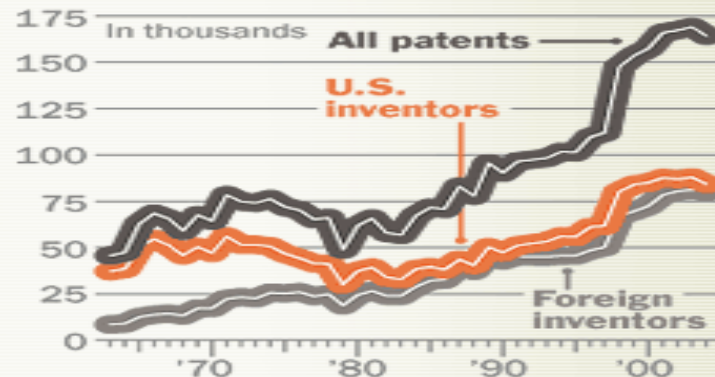
Sources: National Science Foundation; O.E.C.D.; European Commission; National Academy of Sciences; U.S. Patent and Trademark Office

SHOWING THE RESULTS

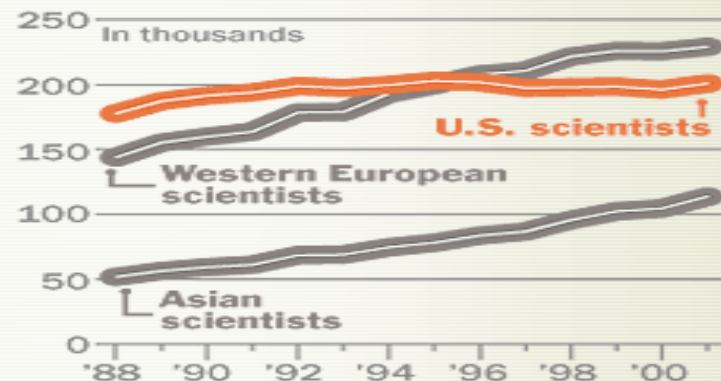
A key measure of innovation is the arrival of new products; another is the publication of articles in scholarly journals. Foreign inventors have nearly caught up in patent grants, and U.S. science publishing has fallen behind Europe's as Asia's surges



U.S. patents granted, by nationality of inventor



Articles published in science and engineering journals



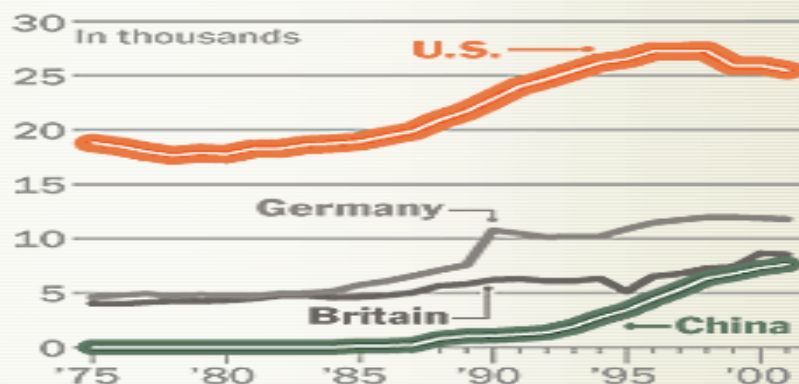
Sources: National Science Foundation; O.E.C.D.; European Commission; National Academy of Sciences; U.S. Patent and Trademark Office

TRAINING THE NEXT WAVE

The U.S. still awards far more science Ph.D.s than any other country, but that number is tapering off as China's is jumping. The U.S. also has the most science majors in the world but ranks 25th when that number is adjusted for population



Doctorates earned in science and engineering fields, by country



*Countries with the highest percentage of 24-year-olds with science degrees**

Finland	13.2%
Hungary	11.9%
France	11.2%
South Korea	11.1%
Singapore	10.9%
Britain	10.7%
Sweden	9.5%
Australia	9.3%
Ireland	8.5%
Russia	8.5%
U.S.	5.7% (25th in the world)

*2000 data, except Singapore (1995), Britain (2001) and Russia (1999)

How to Compete?

- Optimize knowledge-based resources, particularly in science and technology.
- Sustain most fertile environments for new and revitalized industries and the well-paying jobs they bring.

Two Key Challenges

- Creation of High-Quality Jobs for All Americans—not just scientists and engineers
- Respond to Nation's Need for Clean, Affordable, and Reliable Energy

Why Energy?

- Need a focal point for initiative and energy is the key issue facing the nation.
- Three major factors contributing to and influencing economic growth are capital, labor, and energy. The committee's recommendations need to address all three.
- Availability of energy is so critical to nation's economy that changes in that availability can directly impact the nation's Gross Domestic Product and overall health.
- Increases in energy cost or lack of availability influence companies decisions in terms of their production of goods and services. Clean, affordable, and reliable energy, on the other hand, can lead to increased economic output by business and industry.
- Rapid changes in energy prices, such as happens with the world's oil prices, can significantly impact the economy.

Capital

- Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.
- Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs for all Americans that are based on innovation by modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.

Labor

- **Increase America's talent pool by vastly improving K-12 science and mathematics education.**
- **Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.**

Energy

- Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency called the Advanced Research Projects Agency-Energy (ARPA-E).

Four Recommendations

20 Implementation Actions

Committee Consensus

- **Challenges are real and intensifying**
- **K-12 science and math education biggest and most important challenge**
- **Improved education is necessary but not sufficient**
- **Synergy of public-private sectors key to competitiveness**
- **Implementation of all recommendations, not just one—can reverse the erosion of U.S. leadership**

Four Recommendations:

- **Increase America's talent pool by improving K-12 science and math education**
- **Strengthen the long-standing federal investment in basic research in the physical sciences**
- **Develop and retain the best students**
- **Ensure U.S. premier place for innovation by modernizing the patent system and realigning tax policies**

Findings:

- **In 1999, 68% of U.S. 8th grade students received instruction from a mathematics teacher who did not hold a degree or certification in mathematics.**
- **In 2000, 93% of students in grades 5-9 were taught physical science by a teacher lacking a major or certification in the physical sciences (chemistry, geology, general science, or physics).**
- **According to a recent survey, 86% of U.S. voters believe that the U.S. must increase the number of workers with a background in science and mathematics or America's ability to compete in the global economy will be diminished.**

More Competitiveness Indicators

- Fewer than one-third of US 4th grade and 8th grade students performed at or above a level called “proficient” in mathematics; “proficiency” was considered the ability to exhibit competence with challenging subject matter. Alarming, about one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform even basic mathematical computations.
- US 15-year-olds ranked 24th out of 40 countries that participated in a 2003 administration of the Program for International Student Assessment (PISA) examination, which assessed students’ ability to apply mathematical concepts to real-world problems.
- In 1995 (the most recent data available), US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science.

Committee Recommendations Based Upon:

- **High Standards**
- **Measurable results**
- **Integrated curriculum for math and science for grades 6-12**
- **Quality teacher training that is based on content**
- **Incentives to teachers and students based on academic results**
- **Implementation vehicle in each state to manage the programs to ensure quality control and accountability**

Of all its 20 action steps, the committee's highest priority is a program that would annually recruit 10,000 of America's brightest students to the K-12 science and mathematics teaching profession.

Ten Thousand Teachers, Ten Million Minds

- **Recruit 10,000 teachers, Educate 10 million minds: Attract bright students through competitive 4-yr. merit-based scholarships (\$20K/yr) for BS in sciences, engineering, or math with concurrent K-12 science & math teacher certification in exchange for 5 years public service teaching in K-12 public schools**
- **A \$10,000 annual bonus would go to program graduates working in underserved schools in inner cities and rural areas.**
- **Award matching grants, perhaps \$1 million/yr for 5 yrs, to as many as 100 universities and colleges to establish integrated 4-year undergraduate programs leading to bachelor's degrees in science, engineering, or mathematics *with concurrent teacher certification.***

Ten Thousand Teachers, Ten Million Minds

- **Strengthen 250,000 current K-12 science and math teachers through summer institutes—federal matching grants for state-wide and regional 1-2-week summer institutes to upgrade skills of up to 50,000 practicing teachers each summer (Merck Institute for Science Education for K-6 teachers model).**

Ten Thousand Teachers, Ten Million Minds

- **Master's program—federal government provide grants to universities to develop and offer 50,000 current middle- and high school teachers 2-yr, part-time master's degree programs that focus on rigorous science and mathematics content. Teachers who complete this program would receive federally-funded \$10,000 stipends annually for up to 5 yrs provided they remain in the classroom. (model--Univ. Penn. Teachers Institute)**

Ten Thousand Teachers, Ten Million Minds

- **AP/IB (Advanced Placement/International Baccalaureate) training—federal government support training of 70K,000 AP or IB and 80.000 pre-AP or pre-IB instructors to teach advanced courses. Teachers may receive up to \$2000/yr as well as \$100/student who passes an AP or IB exam in math or science**
- **Number who take exam should be increased to 1.5 mil by 2010.**
- **Triple the number of students who pass the tests to 700,000.**
- **Students would receive incentives to both take and pass the exam.**

Because the U.S. does not have a set of national curricula, changing K-12 education is challenging, given that there are almost 15,000 school systems in the U.S. and the average district has only about 6 schools.

Sowing the Seeds

- **Increase federal investment in long-term basic research--** 10%/year over next 7 years focusing on physical sciences, engineering, mathematics, information sciences and DOD basic research funding.
- **Provide early-career researcher grants—**200 grants at \$100,000/year over 5 years to outstanding researchers.
- **Institute National Coordination Office for Advanced Research Instrumentation and Facilities--**\$500 million/year over 5 years.
- **Catalyze high-risk, high-payoff research—**Technical program managers allocated 8% federal research agency budgets for discretionary spending.
- **Institute Presidential Innovation Award—**Recognize persons who develop unique scientific and engineering innovations in the national interest when they occur.

ARPA-E

- Focus on creative out-of-the-box transformational energy research that industry by itself cannot or will not support
- High risk, but potentially dramatic benefits to nation
- Accelerate current research knowledge transformation process to create jobs and address environmental, energy, and security issues
- Research not performed by agency, but universities, start-ups, established firms, and so on
- Staff turn over every 4 years; performance assessments
- Spin-off benefits expected including education of next generation of researchers
- Report to DOE Undersecretary of Science
- Budget: \$300 million first year and increase to \$1 billion per year over 5-6 years.

Why is ARPA-E Needed?

- Nation needs clean, affordable, reliable energy. According to a Secretary of Energy taskforce, the current mix of energy sources is not sustainable in the long run.
- Department of Energy funds basic research through the office of science and applied research and development in focused mechanisms (e.g., solar, nuclear, etc.) through its energy technologies office.
- The proposed ARPA-E would fund research that falls in-between these programs to take full advantage of the nation's investment in research. The committee believes that is not the case today.

Why is DARPA a good model?

- Lean and agile with great deal of independence and ability to start and stop programs based on performance
- DARPA managers are encouraged to fund promising work for long periods in highly flexible programs and to take risks.
- The success of DARPA not just for the nation's defense, but its significant spin-off benefits to national, state, and local government and industry.
- DARPA has also contributed to the education of the next generation of researchers.
- DARPA illustrates the potential ARPA-E could have for the nation.

Best and Brightest

- **Increase US citizens earning science, engineering, and math degrees:**
 - 25,000 new 4-year undergraduate scholarships per year
 - 5,000 new portable graduate fellowships per year
- **Encourage continuing education of current scientists and engineers:** Federal tax credits to employers
- **International students and scholars**
 - Less complex visa processing and extensions
 - New PhDs in S&E: 1-year automatic extension and (if find job) automatic work permit and expedited residency status
 - Skills-based, preferential immigration points system to prioritize US citizenship; Increase H1B visas by 10,000
- **Reform "deemed exports" policy:** Allow access to information and research equipment except those under national security regulations

Incentives for Innovation

- Enhance IP protection for global economy, while allowing research
 - Sufficient resources for Patent and Trademark Office
 - Institute “first-inventor-to-file” system and administrative review after patent granted
 - Shield research uses of patented inventions from infringement liability
 - Change IP laws that impact industries differently
- Make permanent and increase Research & Experimentation tax credit from 20 to 40% of qualifying increase
- Provide financial incentives so US is competitive for long-term innovation-related investment
- Affordable broadband access

Conclusion

- Actions needed not only by federal government, but state and local levels, and each American family
- Need to avoid complacency by assuming US will remain competitive and preeminent in science and technology
- World is changing and need to take action to renew nation's commitment in education, research, and innovation policies so nation's children have jobs

Response to Report

- **Presidents American Competitiveness Initiative** in State of the Union and FY 2007 Budget
- **Protecting America's Competitive Edge Bills** on Energy (S. 2197), Education (S. 2198), and Finance (S.2199) (Senators Domenici, Bingaman, Alexander, Mikulski)
 - 65 cosponsors (34R, 31D)
- **ARPA-E Bill** (S. 2196) (Senators Clinton, Reid, Bingaman)
- **Three House Bills** introduced by Congressman Bart Gordon on Education (HR 4434), ARPA-E (HR 4435), and Research (HR 4596) (Minority, House Science)
- **Democrats Innovation Agenda** (Pelosi)

**Alabama has an important role
to play in revitalizing basic
science education and research
and is well positioned to do so
through the leadership of
AMSTEC**

—Success will require the best efforts of the public and private sectors with strong support from government.

For more information

www.nationalacademies.org/cosepup

PDF of full report is available at no cost by
visiting the following website www.nap.edu