# science progress

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# science progress

# A Nation of Science from the Very Beginning

The impetus for *Science Progress* is the sense within the scientific community that, at many levels, American science policy has lost its way.

**IN NO OTHER COUNTRY** have the great founding figures staked so much on science. At his death, George Washington left a bequest of 50 shares of stock in a canal-construction company to support the founding of a national university where the new nation's youth would be educated in the arts and sciences and would study "the principles of politics and good government." Washington was, of course, a surveyor by trade, considered a highly technical craft in its time.

Benjamin Franklin's intensive study of natural phenomena such as such electricity, meteorology, and refrigeration is less appreciated than his particular inventions, like the lightning rod. But Franklin clearly understood that technological innovation should be based on careful, systematic observation and experimentation, a remarkable intuition that would fully flower only well into the next century. His concrete institutional legacies—the American Philosophical Society, the Franklin Institute, and the University of Pennsylvania—all embody Franklin's enthusiasm for inquiry and innovation.

Thomas Jefferson, whose inventions still fascinate visitors to Monticello, said of himself that "Nature intended me for the tranquil pursuits of science, by rendering them my supreme delight." In more practical terms, Jefferson's founding and stewardship of the Patent Office reflected his view that America must reward creativity in order to achieve its great destiny.

And Jefferson's great and equally complex rival, Alexander Hamilton, was set on a career in medicine in college and attended as many lectures on science as he could. As the architect of the American economy, Hamilton shared with the other founders a vision of the importance of invention as a key to the country's greatness, and sought to facilitate his extraordinarily modern conception of investment, industry, and commerce as an organic system.

In the late 18th century the term science was still virtually interchangeable with natural philosophy. Yet these founders sensed that the trajectory of human knowledge was on a sharply upward course. Influenced by the Scottish and English empiricists, especially David Hume and John Locke, they also seemed to believe that America's aspirations were naturally implied by human nature, an inborn temperament that included certain inherent capacities for inquiry and understanding.

In the 19th century these notions crystallized into a conception of material progress as inevitable, facilitated by science and industry, and indeed from the perspective of the early American progressives—among them Theodore Roosevelt, Robert LaFollette, Woodrow Wilson, William Howard Taft, and William Jennings Bryan—it seemed hard to argue with the idea that progress was steamrolling through history, for all its virtues and vices.

But is material progress also spiritual progress? And in either case is it inevitable? Not all progressives bought into the notion of progress as connected with industry, or do now. Vannevar Bush's famous post-war characterization of science in 1945 as "the endless frontier" was perhaps the high-water mark of American optimism about scientific research as the foundation of a limitless, bountiful American future. As historians have amply documented, social movements of the succeeding decades have called into question both the inevitability and the spiritual satisfactions of scientific progress expressed by Bush, one of the founding fathers of the military industrial complex.

Thus we have on one hand America's astonishing ascent, built to a great extent on the intimate relation between energetic scientific inquiry and a powerful modern state that the founders appear to have intuited. And on the other hand, we have grave doubts that true progress as an outgrowth of material improvement can be taken for granted, or even that it has any meaning. What then is the American narrative of science and progress for the 21st century?

In the largest sense, developing this new narrative is the intellectual challenge that *Science Progress* has set for itself. This effort could hardly be more timely. The impetus for *Science Progress* is the sense within the scientific community that, at many levels, American science policy has lost its way: from doubts about the current administration's commitment to evidence, to concern about political movements that call evolution itself into question, to worries about our ability to sustain our historic lead in basic research. Since our Web launch in October 2007 we have been gratified by the enthusiastic response of scientists, experts in science policy, and leaders in financing innovation.

Our overarching aim is to continue to work out the founders' vision of an American future that remains a great and unfinished experiment and thus is, at its core, a nation of science. sp

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# New Challenges, New Ideas, New Policies

Above all, we have come together at *Science Progress* in search of new ideas and new policies that ensure scientific innovation offers all Americans the opportunity to contribute to the common good.

**OUR NATION TODAY** faces unprecedented challenges to our global political and economic leadership, our national prosperity, our health and well-being, even our once unquestioned post-war dominance in science and technology. Our political leaders on both sides of the aisle claim these challenges can be met with the application of some good old American ingenuity and lots of money. History is on our side, of course, but the challenges are myriad and their complexities unprecedented.

The pages of *Science Progress* now in your hands brim with confidence (we're progressives, after all) in our country's future—optimism that is matched by clear-eyed analysis and complementary policy proposals to meet the many interlocking challenges of the 21st century. Our staff, our advisory board members, and our array of policy experts have embraced *Science Progress* as a unique platform to guide U.S. science, technology, and innovation policymaking in age of overlapping scientific disciplines and almost overwhelming interconnectedness. Above all, though, we have all come together in search of new ideas and new policies that ensure scientific innovation offers all Americans the opportunity to contribute to the national and global common good.

That's why the inaugural edition of this journal begins with the section Innovation and Economic Opportunity. We open with an essay on the seemingly arcane but crucially important question of public policy quality management, followed by a telling examination of the efficacy of diversity in our quest for more innovation and higher productivity. These two essays—and the ones that follow in this section on competitive grants, venture capital, and computer gaming—highlight the importance of encouraging out-of-the-box thinking to boost economic prosperity for all Americans. Money, though, is equally crucial, thus our case for a national innovation agenda, which rounds out the journal's first 20 pages.

Sometimes science best presents itself in classic form—through direct dialogue, or questions and answers to elicit the voice as well as the knowledge of the research at hand. We open our Energy and the Environment section and close our Life Sciences and Public Health section with Q&As to explore directly the latest advances in biofuels and genetics. These discussions also explore new policy proposals germane to progressive ideals of clean and equitable economic and social growth. The Q&As bookend two sections replete with forward-looking analysis of other key science and technology issues, among them water management, green technologies, drug development, contraceptives, and electronic medical records.

In the middle pages of this, our first print edition—visit our online magazine at www.scienceprogress.org—reside our most comprehensive pieces of science and technology policy work, focused on national security. But like the rest of the articles in this journal, these more lengthy reports look beyond the traditional borders of national security to embrace more encompassing definitions of the term befitting the new threats faced by our nation.

This edition's signature policy proposal—"Ubiquity Requires Redundancy: The Case for Federal Investment in Broadband"—calls for multiple broadband connections stretching across the length and breadth of our nation to cope with national security threats posed by radical terrorists, pandemics, and the consequences of more devastating natural disasters spawned by climate change. This detailed focus on telecommunications policymaking to match 21st-century threats is followed by a smaller report on the dual use dangers of biotechnology in military and commercial technologies today at home and abroad, complete with practical policy proposals to bring about global enforcement of realistic oversight mechanisms of the science that will likely dominate the 21st century. We close out the national security section with a report on a 21st-century technology—new high-tech sensors—which could secure the safety of our crumbling 20th-century national infrastructure.

We end this issue of *Science Progress* with perhaps the least discussed but most crucial long-term aspect of science and technology policymaking—how to educate the American people about the importance and relevance of science. Communicating science today is vastly more complicated than it was at any time in the past century, when the certainty of scientific facts and those who discovered them came to reign supreme. Alas, most scientists today still communicate their facts and conclusions from on high to the American people, who increasingly find these arguments understandably unpersuasive due to the cacophony of often contradictory scientific studies.

The series of essays in the Science Communication and Education section challenge scientists and policymakers to do better—to actually engage with the American people in a dialogue when the public expresses concerns about new technologies such as synthetic biology and nanotechnology, and to explain why dueling theories about, say, the possible causes of a particular cancer are as important to understand as the possible cures to which the theories may point. In this way, manufactured controversies about the efficacy of the scientific method by anti-science proponents of, say "intelligent design" over the theory of evolution, can be effectively dismissed by a more scientifically engaged American public.

Communicating the importance of science and technology to the American people helps ensure the innovation policy proposals so key to our country's future prosperity find a willing audience on Capitol Hill and in statehouses around the country. *Science Progress* is designed to tackle both tasks, so take a glance at our Table of Contents, dip into those issues that first catch your eye, but don't limit yourself to what you know and understand. Our purpose here is to shake up U.S. science policy by offering new ideas to new challenges, drawing strength from a diversity of opinions across a range of disciplines. This approach is inherently progressive. It is science progress at its best. sp

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# QUALITY AND INGENUITY ARE INTERTWINED

## Regaining Our Innovative Edge Through Quality Assurance

By Jim Turner and
Maryann Feldman

## It is a metaphor for our times that the average American has never heard of Joseph Juran.

Juran, who died on February 28 at the age of 103, was a giant in the quality movement that revolutionized manufacturing, first in Japan and then in the United States and the rest of the industrialized world. Juran and those who followed him extended quality principles across the entire business sector and into other aspects of society. It is now clear that Juran's views on teamwork and his ideas about continuous improvement and quality assurance management techniques are even more important today to the United States' position as an intellectual and practical world leader in innovation.

But first, a bit more on Juran's critical legacy. Born in a primitive East European village, Juran immigrated to the United States as a child, and at age 21 was one of the first engineers to apply statistical methods to quality inspection in manufacturing. Ultimately, he became Western Electric's corporate Head of Industrial Engineering and then went on to re-engineer military logistics during World War II. On loan from Western Electric to the federal government, Juran led a multi-agency team that redesigned the U.S. armed forces' shipping processes, reducing the amount of paperwork, significantly cutting costs, and aiding the war effort.

After the war, Juran became a full-time quality consultant, and is credited with transforming the Japanese post-war economy. He popularized the Pareto Principle—the idea that 80 percent of potential improvements are due to 20 percent of operations—teaching that the most successful organizations optimize that vital 20 percent first.

Juran's key insight is that process matters. He stressed the importance of empowering individual workers, the reinforcing nature of teamwork and quality circles, and the importance of extending quality management techniques to suppliers and customers. And he taught the importance of benchmarking to understand and meet the challenge of competitors. Japan's embrace of quality management placed it on the road to world manufacturing leadership, as documented in The Machine that Changed the World. Japan's recognition of his contribution led to the award by the Emperor of Japan of the Order of the Sacred Treasure Award, that nation's highest honor. This is why the Japanese were so amused when, in the 1970s, American companies wanted to learn Japanese management techniques. The Japanese believed that they were practicing American management as taught by Juran and his colleague Dr. Edwards Deming.

Juran's book, *Total Quality Management*, is the bible on this topic. At age 82, Juran was the star witness in the Congressional hearings that led to the creation of the Malcolm Baldrige National Quality Award, which honors superior performance in organizations that function at the highest quality level.

## JURAN'S LESSONS FOR AMERICA TODAY

Management guru Peter Drucker stated in a 1996 PBS documentary that "whatever advances American manufacturing has made in the last thirty to forty years, we owe to Joe Juran." Indeed most of the large companies worldwide have embraced his ideas, including U.S. quality award-winning manufacturers Boeing Co., General Motors Corp.'s Cadillac unit, high-end textile and chemicals company Milliken & Co., and Texas Instruments Inc. Yet, U.S. manufacturing today accounts for only 15 percent of our Gross Domestic Product. This is less than Japan, Germany, and other high-wage economies. Why? The reason is that services now dominate our economy, yet Americans often wonder where the service is in our service economy.

Quality principles apply in services as strongly as they do in manufacturing, but the problem is that much of our service and manufacturing sectors still cling to the rigid industrial efficiency production models of Frederick Taylor, the turn-of-the-last-century's most famous efficiency management expert. The high throughput, Taylorist model that treats workers as automatons, quality as an after-the-fact consideration, and customers as uninformed and undemanding still appears to dominate.

Nor are we as a nation aware of how fast our competition is moving. Other countries are taking quality a step further by considering how their governments and educational institutions need to restructure to better accomplish their national goals. Taiwan's industrial parks now often bundle leading research universities and government agencies to provide research and policy expertise for integrated solutions. The result is a nation that has moved from a underdeveloped country famous for cheap goods to the world's largest manufacturer of all manner of computer peripherals—and increasingly the inventor, designer, and manufacturer of cutting-edge electronic technologies.

Or consider Finland, which has coupled its emphasis on quality in business with application of quality principles to its schools, with the goal of empowering its students and teachers. Despite deemphasizing standardized tests, they have raised performance levels to the point where students are among the best in the world, both in standardized tests and adaptability in the workforce upon graduation.

Countries across the globe are aggressively modernizing, and once again, as in the 1970s, the United States is not keeping up. That's why reengineering government through quality management is so essential.

## PUBLIC POLICY QUALITY MANAGEMENT

Ten years ago in the book *The Death of Common Sense*, legal scholar Philip K. Howard documented the rise of rules in American government. We were then and still are a society in which rules and procedures often inhibit creativity and problem solving. Much of government is driven by the same bureaucratic approach that Joe Juran spent a lifetime working to replace.

When people say that they dislike government, they highlight the maze of rules and regulations, the lengthy and seemingly illogical processes, and the difficulty in getting governments to make decisions. Too often, government acts after the fact when something goes wrong—the analog of old-fashioned quality control—rather than working with its constituencies to avoid problems, an approach that lies at the heart of today's quality assurance programs in the private sector.

Once something goes wrong, too often our government embraces an overbroad rule to prevent it from happening again. One shoe bomber and thousands of Americans take off their shoes to comply with a rule that does not make us more secure and does not anticipate the next event.

Joe Juran and his colleagues have shown us the way out. It is now time for the government at all levels, and wherever feasible, to replace end-of-the-line regulation with active participation. A re-engineered regulatory agency should be able to deliver a higher level of public safety by working with companies and all other interested parties on setting commonly acceptable standards that guarantee a high level of public good in a cost-effective manner.

For instance, state auto inspections could be redesigned to increase public safety. Data that they routinely collect could be targeted to that 20 percent of components that cause 80 percent of the safety problems—the 80/20 rule again. Faulty components could be traced back to a manufacturing lot and allow auto companies and their suppliers to correct unusual patterns of wear. Currently wide-ranging recalls happen only after significant and catastrophic failure. Why not solve the problems in situ and work for much smaller recalls well before failure occurs?

Critics will claim that the active participation of government agencies and industries in solving problems will result in what's known as "regulatory capture," in which the industry being regulated commandeers the agency policing it. But that's what happens when regulations are rules-based; companies work hard to change the rules. In contrast, quality assurance management, if properly implemented, replaces regulatory capture with cooperation, and brings public officials, private industry, and consumer and workers groups together to achieve maximum efficiency, innovation, and speed in getting the product or service right the first time.

A government operating on its own priorities at a bureaucratic pace does not deliver timely solutions—just when U.S. international economic competitiveness demands timely action. To be effective in the 21st century, governments need to switch to a quality approach in conducting government business. This means going digital wherever possible, which in turn will necessitate setting privacy-protection for the mining of that data, working with manufacturing and services industries on developing common language, and setting standards to make government/industry interactions as seamless as possible.

In short, it will require a government commitment to excellence in forcing out waste and maximizing efficiency in its functions, and in committing to what is best for private sector entities and the common good. We need to realize that government services are part of the international competitiveness of private companies. Joe Juran championed international benchmarking for companies. We need to benchmark government delivery of services against the most efficient governments in the world. We need to get over assuming that everything in the United States is above average.

Finally, we must recognize our nation's inherent advantages and work to strengthen them as well. We have one of the world's longest traditions of democracy and of productively working together. The Internet has greatly increased the efficiency of democracy by rewarding open systems and by making distributive work and decision-making easier. Premium services from government are one of the offsets we can offer to low wages from other countries.

We have every reason to believe the United States can once again emerge as a world leader in productivity and quality of life if we focus on the vital issues where we can make the greatest improvements; if we err on the side of an open and free society; if we reorganize to empower our entire workforce; and if we update Joe Juran's gift of quality through a commitment on focused, continuous improvement. sp

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INNOVATION


# Diversity Should Power Science

## More Money Is Not the Only Answer

By Scott Page

**WHETHER PUT FORTH** by Vannevar Bush, one of the godfathers of the military-industrial complex, or Richard C. Atkinson, the long-serving head of the National Science Foundation, the case for the funding of basic science remains largely the same *even after 50 years*—investment in basic research produces the knowledge that drives innovation and, in turn, human progress.

The sources and causes of innovation remain mysterious (and will always be so), which in turn requires new thinking about how best to finance innovation. This faith in government funding of basic research rests (first of all) on the proven shortcomings of profit-driven science. The demands of the marketplace obviously create incentives to explore many scientific pursuits, most often practical problems such as how to build faster computer chips, safer allergy medications, and more fuel-efficient cars. One fact should be obvious, businesses won't set out to make the world a better place unless they can make money at it.

That leaves many fundamental questions related to the causes of disease, the forces that create an affluent society, and the maintenance of the earth's ecosystems in need of funding from governments. Finding solutions to existing problems is reason enough to support science research, yet government investment in basic science also encourages unguided exploration, which can result in solutions in search of problems, such as the laser. As odd as this sounds, science often finds answers to problems we didn't even know we had.

So why would I argue that the current science funding model is clearly inadequate to the needs of scientific inquiry? Why is this model antiquated? Because the sources and causes of innovation remain mysterious (and will always be so), which in turn requires new thinking about how best to finance innovation.

## SOURCES OF INNOVATION

Innovation, in economic terms, resides inside the heads of people. People possess different ways of seeing problems and solutions—oftentimes different perspectives depending on the kinds of people viewing particular problems and solutions. People's perspectives are accompanied by ways of searching for solutions to problems, something scientists call heuristics. When confronted with a problem, people encode their (often quite different) perspectives and then apply their particular heuristics to locate new, possibly better, solutions.

Individuals who perform best obviously possess good perspectives and heuristics (think Thomas Edison and his multiplicity of inventions), yet 30 copies of Edison working as a team may be no better than one. In contrast, a diverse team of individual innovators may on average know fewer heuristics each but collectively know more. When a diverse team applies those diverse heuristics, the effects can be superadditive. James Watson plus Francis Crick were far more impressive than either working alone.

On a far larger scale, one reason for Silicon Valley's success is surely its abundance of bright engineers from different academic disciplines and from almost every corner of the globe. Collectively, they out-innovate other technology hotspots with equal brainpower but less diversity.

Government funding of science must take this diversity calculation into account when allocating budgets. Government spending on science today is in effect a giant hedge fund. Despite the huge potential payoffs, this hedge fund won't emerge from the private sector because too often the payoffs aren't appropriable. The Naismith family made little from the invention of basketball, for example, but the world gained immeasurably.

As with any hedge fund, effective government funding of science requires that lots of money gets tossed around. Some investments will yield little, while others will produce enormous dividends. This "portfolio" metaphor for scientific funding leads to an intuition that diversity has value—that basic scientific research should be allocated to diverse research projects. And that intuition is correct—diversity does provide portfolio insurance—yet the value of diversity goes far beyond mere portfolio effects. Diversity can produce superadditive effects.

A breakthrough in one domain can be combined with a breakthrough in another to produce even deeper knowledge. Research on disease transmission by epidemiologists helps us understand the spread of disease. Research by computational social scientists on how to construct large-scale simulations of societies helps us understand how markets work and how economies collapse. When we combine just these two breakthroughs, we're able to construct a third, in the form of high fidelity computational models of disease spread that enable us to learn when and how to intervene.

In short, the mathematics of innovation shows that one plus one often equals three.

## DEVELOPING SCIENTIFIC DIVERSITY

The government can encourage scientific diversity in four ways. First, they can encourage interdisciplinary research through programs such as the National Science Foundation's Integrated Graduate Education Research Traineeship initiative, or IGERT, which funds Ph.D. students in novel, interdisciplinary programs. The diversity of study of the IGERT program breaks through the current incentive structures of the modern academy, which reward progress within disciplines. Well-placed (and sufficiently large) IGERT carrots can provide incentives for scholars to step out of the comfort of their home departments to work with interdisciplinary teams.

Second, the government can continue to support scholars from underrepresented groups. Fewer than two in 100 Ph.D.'s in physics are African American, and fewer than two in 10 are women. Yet, we know from biology, psychology, and economics that the inclusion of women and minorities not only changes the questions being asked within a discipline, but also changes how those questions are answered.

Third, funding must loosen up, and not just the purse strings. Government grants, be they from the National Science Foundation or the National Institutes of Health, often require perfect scores from multiple referees. This tends to bias awards in favor of safer, more conservative grants. Fear of failure, which is unavoidable given that future prospects depend on past successes, exacerbates the tendency toward more mainstream research. Innovation won't be produced by tinkering on the margins of existing approaches.

Aiming big implies failure. That's okay. In its golden era of innovation, Bell Labs demanded a certain failure rate. Too much success signified a lack of experimentation. Breakthroughs in science come from someone seeing a problem in a new way. Government needs to fund the space, resources, and opportunity for scientists to step outside of their usual boxes and fail. That's impossible if grant renewals require success at every step.

Fourth, the government can make commitments to big problems—finding a clean source of energy, colonizing Mars, curing cancer, eradicating poverty and disease. Big problems create diversity by shifting attention away from techniques and toward solutions. Thus, they spawn multiple approaches.

Big problems almost always unpack into lots of smaller problems, each of which requires diverse ways of thinking. And big problems, such as the space program, make science focal and fun, encouraging more people, and more diverse people, to choose science as a career.

## INNOVATION FOR THE COMMON GOOD

Many of the problems we face today are complex. They consist of diverse, dynamically interconnected parts. Certainly climate change, epidemics, terrorism, and poverty fit into that category.

Other problems are just plain difficult: finding a workable form of fusion, understanding protein folding, and curing diseases. We won't solve these problems, the difficult or the complex ones, with current modest levels of funding for well-established routes of inquiry. We need more funding and more ways of thinking.

The aim of governmental scientific funding is the production of innovation that improves the lives of everyone, and the seeds of innovation lie in seeing problems in new ways. The funding of science should reflect that by rewarding diverse thinkers, funding interdisciplinary research, broadening the pool of scholars, and focusing attention on big problems. sp

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FINANCING SCIENCE


ADAPTED FROM FLICKR/KEVINDOOLEY

# Maine's Tradition of Innovation

## $50 Million in New Grants Can Drive R&D

By Hannah Pingree

**UP UNTIL THE MID-1800S,** paper was made mostly out of rags. The paper industry lived and died on the availability of discarded clothes and other cloth materials that could be beaten into a pulp and poured into molds to make paper.

Papermaking began in Maine in the 1730s, as the state's rivers provided power and clean water for the papermaking process. The industry in general was successful—and Maine papermakers, like those in many other states with clean rivers, made a good living.

But the state's paper boon didn't really begin until a rag shortage in the 1850s, along with increasing demand for paper, forced European and American inventors to search for new resources to make pulp. They quickly discovered that wood was an efficient resource for paper, and new wood-based paper mills began to spring up, primarily in the Northeast.

Developers saw an opportunity in Maine, the nation's most densely-forested state. The first wood pulp in Maine was produced in the basement of a sawmill in 1868, where the workers made one ton of pulp per day. By 1875 the S.D. Warren mill in Westbrook was blending wood fibers with rag pulp, and five years later it was the largest paper mill in the world.

It was one of those rare confluences of a need, an idea, an abundance of resources, and the money to make it happen all meeting in the same place at the same time—the perfect formula for innovation to flourish. That confluence allowed the paper industry to serve as the primary driver of Maine's economy for the next 150 years.

But times change. As globalization makes it more and more difficult for Maine to compete as a paper producer, the state is looking to preserve the industry of the past while moving to a new economic driver for the future. Other traditional Maine industries—like fishing and farming—are struggling, and rely on innovation to remain competitive and to grow into the 21st century.

Last year, the Maine Legislature passed a historic bond package to send out for ratification by voters in three separate elections, and Maine voters then approved one of the largest single investments in the package—$50 million in competitive grants for research and development, to be issued through the Maine Technology Institute.

MTI will award a mix of large and small grants to both entrenched and fledgling research firms that can prove that their investment will provide the biggest return. With a total of $50 million available to the best and the brightest—and at least $50 million in matching funds expected for winning grants—there will be no shortage of fresh ideas and innovative pitches. Some of these ideas will venture boldly into uncharted new territory; others will improve old technology to preserve traditional state industries like pulp making, fishing, and farming.

Historically, state investments in research and development have paid off. The Jackson Laboratory, based on Mount Desert Island in Penobscot Bay, is now the world's largest mammalian genetics research institute. Jackson Labs has been a regular beneficiary of state investment, and it has developed into one of the world's premier biomedical research facilities. Targeted investments in boatbuilding and marine research and development have established the state as an international leader in those industries as well.

To bring the paper story full circle, some new R&D money is likely to fund groundbreaking research happening at the University of Maine on turning wood product waste cellulose into ethanol. Scientists have discovered—and this may sound familiar—that wood ethanol is far cheaper to produce than ethanol made from corn. This research will likely add value to the bottom line of Maine's current paper industry and simultaneously reduce the state's carbon footprint.

In the late 1960s, mothers of students at a prep school in Seattle used proceeds from the school's rummage sale to buy an ASR-33 teletype terminal and a block of computer time on a General Electric computer. For such a small investment, the computer was an enormous hit with the junior high school-aged students, and access time to the GE computer was in high demand—especially for a group of thirteen-year-olds who saw a world open before their eyes.

Among them was one student who discovered an almost supernatural knack for deciphering and writing codes. He founded his first software company at age 14, developed payroll processing and traffic-counting software through his teens, and at age 20 founded Microsoft—which went on to become the biggest software company in the world.

Bill Gates knew that he excelled at science and math from a young age, but he didn't know the potential behind it until a small investment made at the right time with rummage sale proceeds allowed him to realize it. It's one of innovation's most famous success stories, and it's based on the same basic concept of a need, an idea, and a resource all meeting at the right time.

The competitive grants awarded by MTI will go to the people with the best ideas who can prove the best return on the investment. The Maine Technology Institute is tasked with spotting potential—which is a challenging, exciting, and essential charge. Somewhere in Maine could be another Bill Gates, and he or she could be one small investment away from discovering an ability to change the world. Even more likely, somewhere in the state is the next paper industry—a future engine that could drive the economy for centuries.

Somewhere in Maine are a need, an idea, and a resource that are all meeting at the same place at the same time. sp

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*Hannah Pingree (D-North Haven) is the Maine House Majority Leader.*

INNOVATION IN THE CLASSROOM

ADAPTED FROM ISTOCKPHOTO AND FEDERATION OF AMERICAN SCIENTISTS

# More Tests, Please

## No Child Left Behind Debate Misses the Point

By Henry Kelly

THE NO CHILD LEFT BEHIND ACT has created the wrong kind of debate about testing. Given the lack of new funding, many states are jiggering their tests to obscure the failure of poorly performing schools and undermining the accountability that was the core goal of the program. Others are attempting to opt out of the program. The process is wasteful, confusing to students, and fails to produce the information that education enterprises so badly need.

Instead, we should first engage in a national debate about the expertise students need to acquire in order to prosper in the 21st century, and only then settle on how best to measure their progress. The interactive methods used in computer games represent some of the most powerful ways to test newly acquired skills, but understanding why they are so useful requires a clear recognition of why our current testing procedures are thoroughly outdated.

Despite all the complaints about the numerous tests mandated by NCLB, the problem is not too many tests but too few tests. High stakes, standardized tests are an artifact of a mass production model imposed on education out of necessity during the last century. Traditional tests measure performance in situations that will seldom, if ever, occur in an actual job. Someone trained to solve problems working in isolation, with no access to reference material and no ability to consult experts, is largely useless in today's economy.

But consider the ideal classroom scenario: An instructor able to spend plenty of time with each individual student, constantly challenging them, asking probing questions, and presenting increasingly complex challenges tailored to the needs of each student. By the time a test is taken the student should have run through the material enough times that they and their instructors have high confidence in success.

These powerful methods aren't used in standard classrooms for two obvious reasons—they're unaffordable and we continue to think of the classroom as they did 200 years ago. Yet a solution is available from an unexpected source—computer games.

The average U.S. teenage boy spends about 14 hours a week glued to computer games.[1] Most adults can't imagine how the lessons of Super Mario could be applied to high school science or history, but consider that a good game captures and holds a player's attention with a series of compelling goals, each slightly beyond the player's current abilities. A great game draws players in what designers call "the flow," where they will try, fail, and try again, working for hours to master the skills needed to win.

What's striking, of course, is that they're also being continuously tested. Tests are an integral part of winning, and players accept that they will fail before they master the skills needed to move on. If you keep crashing your simulated aircraft, you know that you've got to work harder. Winning at the most advanced levels of game play requires players to draw on a huge body of knowledge and experience.

Winning many games, moreover, often requires more than mastery of specific skills. They require precisely the skills that the Partnership for 21st Century Skills recently reported are in greatest demand in today's economy: gathering evidence, making decisions under uncertainty, evaluating options, and (in the case of multiplayer games) working effectively as a member of a team.[2]

The U.S. Department of Defense, which unlike most organizations is unembarrassed about having its employees play (war) games, has come to appreciate the power of simulation-based games to teach and test individuals and teams. They have convincing evidence that skills acquired through simulations translate into performance in the field.[3]

Simulation-based instruction can reproduce the complexity, confusion, and tension of field conditions so faithfully that the success a soldier gains in the simulation translates directly into reliable performance during first real combat experience. This powerful transfer from simulation to practice has also been demonstrated for pilots and several areas of surgery.[4] Surely it's possible to create challenges in biology, history, or engineering that can capture and hold attention.

Building software to teach and test complex skills is expensive. Several billion dollars were invested and lost in education technologies toward the end of the dot-com boom a decade ago, and investors have been wary ever since. Schools and universities are a notoriously poor market for innovations, in part because of an understandable reluctance to take risks with unproven approaches. But as a result, an enormous opportunity is being lost.

The federal government should fill gaps by funding basic science research, development, testing and evaluation that can be picked up by private investors. We can do this in new technologies for learning and create markets for robust new products…or we can continue to fool ourselves that our education system can be fixed with ad hoc testing standards. sp

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*Henry Kelly, Ph.D., is the President of the Federation of American Scientists, and Chairman of the Board of Directors for Scientists and Engineers for America.*

**NOTES**

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3 Fletcher, Dexter. "Advanced Technology for Defense Training." Institute of Defense Analysis. June 2006. http://www.digitalpromise.org/newsite/Resources/Research/Dexter_Fletcher_Jun14.pdf.

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FINANCING SCIENCE

AP PHOTO/PAUL SAKUMA

# Supporting Venture Innovation

## Venture Capital Drives U.S. Competitiveness

By Joseph W. Bartlett

**THERE IS ONE SAFE CORE ASSUMPTION** about the future of U.S. economic prosperity: Without our nation's robust venture capital-backed, entrepreneur-driven, tech-flavored industries and services, which are today still largely unique to the United States, our country is an also ran, its global influence, power, and leadership fated to diminish over the course of the 21st century.

That said, monopolies never last forever. Our clear lead in what I call the EVITA economy—Entrepreneurial, Venture-backed, Information–dependent, Technology-flavored Activity—now faces rising competitive challenges from global competitors—a natural, inevitable, and, of course, healthy phenomenon. Indeed, the good news is that an innovation-led global economy is certain to prosper exponentially, in this country and globally, given the tsunami of explosive advances in science and technology the world is currently experiencing.

Unfortunately, serious (and unhealthy) challenges to the bedrock of our nation's entrepreneurial, innovation-led economy—start-up technology companies of all stripes—threaten to limit our economy's ability to remain hyper-competitive across a range of existing and emerging high-technology industries and services. The reasons are manifold but largely stem from unintended consequences resulting from the insufficient allocation of financial and human capital and misguided policymaking. This essay will first define our EVITA economy and then suggest a blueprint for future U.S. economic policy designed to grow innovative new tech companies intelligently and productively, yielding benefits that are socially positive, widely distributed, and fairly allocated.

## THE EVITA ECONOMY

The United States is unusual in that many of its strategically vital corporations are young and competitive, contributing enormously to our national prosperity. In 1990, Microsoft Corp., Dell Computer Co., and Cisco Systems Inc. had combined sales of $2 billion. By 2000, their combined sales hit $80 billion before leveling out at around $90 billion in this decade as they gained blue chip status. Such growth exemplifies why companies backed by venture capital generate twice the sales, pay three times the federal tax and invest far more heavily in research and development than their traditionally financed counterparts.[1]

"Entrepreneurship is what enables American-style capitalism to be generative and self-renewing," observes Carl Schramm, head of the primary U.S. research institute on venture capital, the Kauffman Foundation. Schramm, however, then adds a cautionary note: "The system that generates and supports entrepreneurship in the United States is surprisingly unappreciated."[2]

My take on the subject: Schramm is putting it mildly. For three decades, venture capital-backed startup companies have been the job-creating engine of the U.S. economy. According to a study by the consulting firm Global Insight released by the National Venture Capital Association recently, startups backed by venture capital since 1970 today employ 10 million Americans, and in 2005 generated sales of $2.1 trillion. These companies employ over 9 percent of the U.S. private-sector work force and account for an astounding 16.6 percent of GDP.

This is amazing when you consider that the $23 billion invested by venture capitalists in 2005 represented only 0.2 percent of GDP. Talk about a bang for your buck. These companies—from Apple Computer Co., Intel Corp., Cisco, Amgen Inc., FedEx Corp., and Google Inc. to the up-and-coming mobile technology and lifesaving drug and device companies of today—have generated far higher than average wage growth, have accounted for a significant and growing proportion of U.S. civilian research and development, and have spawned some of the most innovative products, services, and business models of our era.

But we ain't seen nothing yet. Giant technological leaps are in their infancy. If all we do is develop biotechnology innovations currently under development, then an average (and active) life span of 100 years is a cinch. Fossil fuels will be, in fact, fossils. Management information systems will revolutionize health care as computer-driven artificial intelligence facilitates diagnoses. Across our economy, one "pipe" will carry interactive video, audio, and the Internet into every home. Global Positioning System-driven satellite systems will drive (literally) every terrestrial vehicle, air, and sea vessel. And this is only the low hanging fruit. According to world class physicist Freeman Dyson:

> *Two facts about the coming century are agreed on by almost everyone. Biology is now bigger than physics, as measured by the size of budgets, by the size of the workforce, or by the output of major discoveries; and biology is likely to remain the biggest part of science through the twenty-first century. Biology is also more important than physics, as measured by its economic consequences, by its ethical implications, or by its effects on human welfare.*

These facts raise an interesting question. Will the domestication of high technology, which we have seen marching from triumph to triumph with the advent of personal computers and GPS receivers and digital cameras, soon be extended from physical technology to biotechnology? I believe that the answer to this question is yes. Here I am bold enough to make a definite prediction. I predict that the domestication of biotechnology will dominate our lives during the next fifty years at least as much as the domestication of computers has dominated our lives during the previous fifty years.

Yet serious impediments exist in our capital markets today which could well inhibit venture capital-backed startups from commercializing these existing and future technologies, among them: too many notional "public" companies whose shares are too small to trade unless promoted by unscrupulous crooks; too few opportunities for young high-tech companies to go public through an initial public offering without sharing a stock market listing with these crooks; not enough equity-flavored compensation—options—for gifted managers;[3] and not enough sensible tax incentives.[4]

## ENHANCING THE EVITA ECONOMY

The first challenge, then, is for public policymakers to examine federal regulations so that our economic and financial policies foster entrepreneurialism, not only to preserve the EVITA economy in its present form—by attacking bureaucratic micromanagement that violates the *primum non nocere* (first do no harm) principle—but also to unshackle capital-raising opportunities for young tech startups so that they can grow exponentially by matching the growth in scientific and technological innovations which loom ahead of us and, in the process, spread the benefits to all willing to put in the necessary elbow grease.

Policymaking opportunities to boost innovative companies would facilitate the flow of more private capital into early-stage startups so as to minimize a palpable financing gap between available capital and promising proposals. And good policies would reform the irrational blockage in the pipeline between university research labs and venture investors, an aberration which has minimized the ability of universities and medical schools to commercialize technology through spin outs in which the lab owns a meaningful equity interest.

It's also important to enable investors below the level of multimillionaire angels to diversify a prudent portion of their investment portfolios into well managed venture funds through 401(k) and IRA pension plans by tweaking the Business Development Company amendments to the Investment Company Act. And we need to spread venture capital-driven entrepreneurialism beyond the East and West Coasts into communities across the United States by promoting regional innovation centers of excellence.

Each of these policy-reform measures will require careful analysis before implementation. But none of them is difficult to envision as part of a concerted effort to create more venture capital-backed opportunities for entrepreneurs across our country. sp

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### NOTES

1 Companies backed by venture capital generate $643 in sales for every $1,000 in assets, compared with traditional companies, which have only $391 in sales. Venture-backed firms also spend considerably more m money on research and development costs: $44 per $1,000 in assets compared with $15 for others. In 2003, approximately 11 of every 100 working adults in the United States were engaged in entrepreneurial activity, either starting a business or playing a lead role in one less than three and a half years old. That rate is higher than any in Europe and roughly twice that of Germany or the United Kingdom.

2 Schramm, "Building Entrepreneurial Economies," *Foreign Affairs*, Jul/Aug. 2004.

3 Bartlett & Lundberg, "New Executive Compensation Model," available at http://www.fr.com/news/articledetail.cfm?articleid=723.

4 As William Megginson observers concerning the influence of European governments on private equity: European governments have long taken an activist approach to the promotion of VC investment. Unfortunately, both academic research and anecdotal evidence indicates that government efforts to promote a robust entrepreneurial sector would probably be better focused on eliminating regulatory roadblocks, lowering taxes, and providing a more favorable overall business climate than on attempting to directly identify and fund 'sunrise' industries. ...

5 See www.vcexperts.com, Book 19, *The Encyclopedia of Private Equity and Venture Capital*, "New Trading Platforms: Alternative Investment Market ("AIM"); NYSE Arca; The Pink Sheets."

FINANCING SCIENCE

PHOTODISC

# The Flashing Light on America's Dashboard

## The Case for a National Innovation Agenda

By Tom Kalil

**EARLIER THIS YEAR,** the National Science Board released "Science and Engineering Indicators 2008," the Board's biennial report on the state of science and engineering research and education in the United States. But in addition, the governing board of the National Science Foundation also felt compelled to release a companion report to highlight the policy implications of their findings.

This report, entitled "Research and Development: Essential Foundation for U.S. Competitiveness in a Global Economy," concludes that the current decline in support for basic research by both industry and government could "have severe implications for U.S. competitiveness in international markets and for highly skilled and manufacturing jobs at home." Specifically, the National Science Board—established by Congress in 1950 to provide policy advice to the president and Congress on a wide range of science and engineering issues—found that:

- The U.S. high-tech trade deficit has jumped to $132 billion in 2005, the last year complete data was available, from $32 billion in 2000.
- Federal government support for academic research and development began falling in 2005 for the first time in a quarter-century.
- Private industry support for basic research has also been stagnant or declining. Basic research published in peer reviewed journals by industrial researchers declined by 30 percent in the last decade. The number of physics publications by industrial researches dropped to only 300 in 2005, from nearly 1,000 in 1988.

Another study commissioned by the National Science Foundation concluded that if current trends continue, “China will soon pass the United States in the critical ability to develop basic science and technology, turn those developments into products and services—and then market them to the world.”

The NSB’s report strengthens the case for bold, decisive action to restore America’s scientific and technological leadership. In “A National Innovation Agenda,” a Center for American Progress paper published last year, John Irons and I set forth a detailed set of policy recommendations for doing just that. As part of the Center’s economic plan for the next administration, we called for:

- Doubling the research budgets of key science agencies such as the National Institutes of Health, the National Institute of Standards and Technology, the Department of Energy’s Office of Science, and providing even larger increases (10 percent per year) for the National Science Foundation and the Defense Department.
- Maximizing the effect of this investment by increasing support for university–industry collaborations and high-risk, high-return research. This would help replace the void left by the decline of industrial basic research documented by the National Science Board.
- Harnessing science and technology to address some of the “grand challenges” of the 21st century, such as the transition to a low-carbon economy that will reduce our emissions of greenhouse gases while creating millions of “green collar jobs,” or the development of new learning technologies that are as effective as a personal tutor and compelling as the best video game.
- Spurring private sector investment in innovation by making the research and experimentation tax credit permanent and providing tax incentives for investment in next generation broadband networks.
- Ensuring that America’s workforce has world-class skills in science, technology, engineering, and mathematics. This will require upgrading the STEM skills of the existing workforce, improving K-12 math and science education, encouraging more students to receive undergraduate and graduate degrees in STEM fields, and creating a “fast track” employment-based visa for foreign students that receive an advanced technical degree from U.S. universities.

Of course, the National Science Board is only the latest in a long series of reports that document the erosion of America’s scientific and technological leadership. Unfortunately, although President Bush and Congress pledged to address this with the American Competitive Initiative and the America COMPETES legislation, they failed to make any significant progress on this agenda in 2007.

The National Science Foundation’s research received a paltry one percent increase, the budget of the National Institutes of Health budget is down 10 percent in real terms from 2004, and the research and experimentation tax credit was allowed to expire in December 2007 for the 13th time. Congress slashed funding in the Department of Energy’s high-energy physics budget, which will force institutions such as the Fermilab, the Argonne National Laboratory, and the Stanford Linear Accelerator Center to stop important research projects and fire scientists.

This failure to act is unacceptable. It is critical that the next president make science, technology, and innovation a top priority. The future economic prosperity of our nation and our people depends upon it. sp

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*Tom Kalil is a Senior Fellow at the Center for American Progress and an advisory board member of* Science Progress.

# The Path to Better Biofuels

## ALEX FARRELL ON THE LATEST LAND USE STUDIES

Interview by Andrew Plemmons Pratt

**TWO STUDIES** indicating that biofuel production may emit more greenhouse gases than the gasoline the fuels displace appeared this February in *Science*. Mainstream media headlines were quick to declare biofuels a threat to the planet. But a knee-jerk response to the latest research could obscure the fruitful guidance the new studies provide and confuse the policies that reduce emissions with those that pump more carbon into the air. Biofuels are not necessarily bad, but growing feedstocks on land that competes for food or wilderness is counterproductive. The studies focus on this land use issue and the carbon released when farmers in the United States convert forests or grasslands to cropland to make up for the grain diverted to biofuel production. The new calculations indicate that while many promising feedstocks do absorb carbon as they grow and do offset emissions from the gasoline they replace, it can take decades or centuries for absorption and displacement to balance out the carbon released from converting the land and sacrificing the previous ecosystems.

To better understand the policy implications of the new work and how it can steer farmers and policy makers towards better biofuels, *Science Progress* spoke with the late Alex Farrell, who was an associate professor in the Energy and Resources Group at the University of California, Berkeley. Farrell died in April. As his colleague Dan Kammen, a professor in the Energy and Resources Group and of public policy, said at the time, he was "one of the leading lights in the area of low-carbon fuels and energy systems." Kammen added that, "The trajectory of his career and his contributions were both impressive."

**ANDREW PLEMMONS PRATT, *SCIENCE PROGRESS*:** These latest papers, from the Searchinger group and the Nature Conservancy/University of Minnesota group, claim that previous studies of carbon lifecycle emissions of biofuels ignored land use. This seems like a substantial oversight. How did previous researchers miss this, and how significant are these revisions to previous emissions estimates?

**FARRELL:** The Searchinger paper is a very important paper. They have made the first effort to quantify the effects of producing biofuels as they ripple through the global economy. Other people have looked at this in the past, but not in the same kind of way. Mark Delucchi from the University of California-Davis has looked at this, and you can find research papers on his website. But the reason it has tended not to be evaluated very much in the past is that it's a difficult thing to do. You need to use a model of the global economy, and no one's really tried before.

The most important thing is to think about land. Using land to produce biofuels essentially competes with using land for food production or keeping land in wilderness. We have three possible ways to use land: wilderness, fuel production, and food production. The way we produce biofuels today, if you do one, you don't really get a chance to do the other. You have to account for wilderness—rainforests, or even grasslands here in the United States—because these lands have a lot of stored carbon in them. So when you convert the wilderness—weather it's grassland or rainforest—into an agricultural operation of some sort, you release a lot of this carbon. Usually, you're burning the material on the surface, and turning over the soil so it gets oxidized. It's the release of carbon dioxide from the conversion of the wilderness to agricultural production that is the problem.

I'll give you a quick example to understand why it is a little complicated to understand how you might calculate this value. Imagine that I am a corn farmer and that I am in a corn/soy rotation. One year I plant corn; next year I plant soy, and back and forth. You build an ethanol plant near me and I decide I'm going to continuous corn. What that means is that the soy production is now less in the United States than it would have been otherwise. And so U.S. exports for soy go down a little bit compared to what they would have been without this ethanol plant. The price of soy internationally goes up just a little bit, and now farmers all over the world have an incentive to either farm a little more intensively—to use a little more pesticide, for instance—or to accelerate the expansion of wilderness land for agricultural production. This is in the context of expanding populations and people eating more meat, etc. But it is an effect that exists because we have a global economy.

This expansion—because we've got more ethanol production that is now placing land in competition for food and for wilderness—yields these greenhouse gas emissions. That's the basic effect. Other people have not looked at it partially because it's a very challenging to simulate all those market interactions, and partially because the other part of the calculation, a direct process emission, is also relatively challenging, and so people have just been working on the direct emissions part for the last several years.

***SP*:** Are biofuels bad? A lot of headlines over the past few days suggest just that.

**FARRELL:** The answer is "not necessarily." Biofuels are not necessarily bad. What really matters to answer that question is how the material for the biofuel is produced. If the material for the biofuel is produced on land so that it competes with wilderness and food, that's a problem. But if it's produced in a way that does not compete for land with other uses like wilderness and food, then you probably avoid most or all of the problems. And there are ways to do this. There are at least three strategies to make what I call "better biofuels."

The first strategy is to use waste and residues—things that really are waste that are not otherwise used. Many of them are things that we can turn into biofuels.

The second strategy is to use land that does not compete for wilderness or food. This could be severely degraded land or marginal land that you can't get a crop on. There's a proposal to grow mixed prairie grasses on degraded land in the Midwest and to harvest it a couple of times a year, allowing the carbon in the soil to continue to build up and produce a very healthy soil bank. But you could also restore degraded land to natural ecosystems and you should consider that option, too.

The third strategy would be to integrate the production of biofuel feedstocks with food production. We don't do that very much right now. It's a little bit more subtle, so let me give you an example. In California, there are some farmers who cannot make a profit on a crop in the wintertime, but they could grow a cover crop—alfalfa, or mustard, or clover—if they wanted to, but they can't really make enough money doing it. But if they could take this cover crop and sell it for biofuel production, they could actually make a profit and not effect food yields whatsoever.

So there are three strategies that can help solve this problem and that can help develop these better biofuels. An important feature of these three strategies is that they all require advanced technologies, whether it's cellulosic ethanol production, or growing algae in the desert. The desert does not compete for the use of land for food or for wilderness because there's not very much carbon in desert wilderness. There are several different strategies, but they all require advanced technologies, and that's the way out of this problem.

***SP*:** Could these new reports damage the policy making process with regard to clean fuels? What should policymakers take away from the reports?

**FARRELL:** I think the most important lesson to take away from these newest reports is that not all biofuels are created equal. If we want clean biofuels, then we need to demand or incentivize clean biofuels. And recent policy decisions are moving in that direction. Let me mention just two.

One is in California. We have the low carbon fuel standard here in California. Also, in the Lieberman-Warner bill, there is an emission cap that would include transportation. So those types of policies that actually measure what we're interested in—which is low greenhouse gas emissions, among other things—those are the right kind of policies, and they provide the correct incentives to allow companies to bring these advanced technologies to the market, and for farmers to figure out how to grow better biofuels and produce them.

The second one that I would mention is the recent energy bill, which includes some provisions for advanced biofuels that require a standard of performance for low greenhouse gases, with different types of performance standards for different types of fuels. Those parts of the provision are very important. They will help move the biofuels industry in the right direction. In fact they're essential to the biofuel industry, because those kinds of incentives will enable to biofuel industry to develop and sell the products that will have a market in the future. The way out is to create markets for these greener biofuels, as well as providing research and development support. We have some of that already, but we could certainly use more.

***SP*:** Will current renewable fuel standards push biofuels in the right direction?

**FARRELL:** I think it's important to say that the current renewable fuel standard also has provisions that grandfather in the current corn ethanol industry, and over time we need to think of a strategy to help transform that industry, giving it a much cleaner approach. It might be possible, for instance, to retrofit the existing biorefineries. Attending to that is correct, but we need to get these technologies in place first, and I do think there is some urgency to do this because the climate problem is an important one; it's getting worse as time goes on.

***SP*:** The Searchinger paper in particular seems to conclude that biofuel production will necessarily increase food prices. What's the effect on food prices of increasing biofuel production both domestically and internationally? You were saying this is a complicated issue that we're only beginning to understand. Is this going to be harder on developing nations than it's going to be on the U.S.?

**FARRELL:** Unfortunately, I think the answer to that question is probably yes. I think it's important to say that the Searchinger paper is the first attempt to calculate these effects. This calculation of how biofuel production ripples through the global economy is difficult, and I would hope to see other individuals and groups attempt do these calculations and come up with these sorts of estimates, because it's an important thing to look at. The magnitude of the effect is not at all clear, but I think it is clear that there is an effect. That said, the people who will individually be hurt the most will be very low income people in developing counties who have to buy their food. The reason is that in the United States food prices will not change very much because the actual cost of the raw material that goes into food, like the corn that goes into the corn products that we eat, is pretty small compared to the processing and the packaging. But for people who are relatively low income in developing countries, the actual price of the commodity itself is a very high portion of the actual price that they pay, and they can barely afford to buy some of these food products. Because the basic mechanism is that increased demand and competition increases the price for the basic product—whether it's corn or vegetable oil—that is going to lead to some people being less able to afford food. But we can get away from that problem by getting away from biofuels that compete for food production and that compete for wilderness.

***SP*:** How do these current reports influence thinking about the transition that biofuels offer as a bridge to solutions that will get us to the greenhouse gas emissions targets? Are biofuels a bridge technology to other better solutions, or are they a useful end in and of themselves?

One of the questions will be, "What is the mix between biofuels, electricity, hydrogen, and other things that we might imagine?"

**FARRELL:** I think that these "better biofuels" that I have in mind, and that people are working on right now, could be part of the solution in the end if they're done right. Let's be clear that there are pilot plants that are funded by the U.S. Department of Energy that are being built right now. One of the questions will be, "What is the mix between biofuels, electricity, hydrogen, and other things that we might imagine?" So I do think there is almost certainly a role for biofuels in the long future. A combination of innovative technologies and policies that get the industry to move in the right direction will get us there.

***SP*:** What is the final lesson?

**FARRELL:** This will be a very important economic issue for developing countries that have planned to export biofuels. Understanding how to help them develop their economies while preserving their forests and their ecosystems is a very important task. To some degree, this points to the problem that we are undervaluing forests and grasslands and wilderness for their carbon storage. If we were to fix that problem—which was discussed at some length at the Bali climate convention a few months ago—we would go a long way to fixing this overall problem. sp

ENVIRONMENTAL POLICY

NOAA FISHERIES

# Restoring the Waters

## 21st Century Progressive Movement at Work

By Sarah Bates

**ONE OF THE MOST DISTINCTIVE** physical legacies of the 19th century progressive era in the United States was an ambitious and successful effort to harness the mighty western rivers to provide water for irrigation and electricity for growing cities and industries. Today, nearly every river in the West is regulated by dams, locks, or diversions.

These dams and their extensive water distribution facilities fueled an engine of growth and prosperity that drew millions to the region. The dams on the Colorado River, for example, are capable of storing four years' worth of river flow. Problem is, the very infrastructure that makes the desert bloom has nearly destroyed the river's native fishery and has fundamentally altered the ecosystem it supports.

The same is true across the region. Damaged rivers and wetlands, endangered fish and wildlife, and impaired communities and economies that rely on healthy, intact river systems are commonplace today. But the fact that our monumental western water infrastructure has hurt the environment is old news. The good news is the vast amount of work that is now underway to restore the region's rivers and their associated natural and human communities—developments that are not so well known.

We are, in fact, already well embarked upon a 21st century progressive era in the American West—one in which the federal agencies once known for the cubic yards of concrete they poured are now directing increasingly significant resources to restore rivers, wetlands, and riparian corridors. This is an encouraging movement, and one worth celebrating, encouraging, and publicly embracing.

The U.S. Bureau of Reclamation, for example, got its start in 1902 in the same burst of legislation that gave rise to the Newlands Irrigation Project, which diverted water from the Truckee River near the California–Nevada border to irrigate high-elevation desert farms. Unfortunately, the water flowing to Newlands depleted the river's historical terminus, Pyramid Lake. Eventually, lake levels fell by 75 to 80 feet, nearly wiping out the native fish populations and thus preventing the Pyramid Lake Paiutes, whose reservation surrounds the lake, from exercising their historical fishing rights.

Decades later, following lawsuits and lengthy negotiations, Congress enacted in 1990 the Truckee-Carson Settlement Act, which directed the Bureau of Reclamation and other parties—including the states of California and Nevada, other federal agencies, the Paiute tribe, and private water interests—to find new ways to work together to restore the river, the lake, and the fisheries. This has proved to be a challenging mandate, but today an impressive multi-party restoration initiative is well underway.

The manager of this project for the Bureau of Reclamation, Elizabeth Rieke, previously served as the assistant secretary of water and science for the U.S. Department of the Interior. She possesses a keen grasp of federal water policy. Commenting on the changing mandates for federal water projects at a conference sponsored by the Buffalo Bill Historical Center in 2005, Rieke remarked: "We can build them, operate them, modify them, re-operate them, we can make them safe and secure, and we can take them down."

Her message, in short, was that the same technical expertise that erected the West's great water projects can be harnessed in new ways to benefit a broader range of public values.

For its part, the U.S. Army Corps of Engineers—the agency responsible for constructing the largest flood-control dams in the nation—has embraced environmental protection and restoration as explicit objectives of its water resource management mission. In one example of its commitment to this new direction, the Corps entered into a "Sustainable Rivers" partnership with The Nature Conservancy in 2002 aimed at improving dam management to restore ecological health in the affected rivers.

River restoration projects are proliferating throughout the Rocky Mountain West. In some cases this means that dams are coming out of the rivers they once plugged. More commonly, federal agencies are operating dams in new ways to re-create historical downstream river conditions. In many places, restoration means putting the curves back into artificially straightened rivers, replacing riprap (stone or rubble dumped along river shores to combat erosion) with native vegetation to secure the banks, and "daylighting" rivers once buried in steel culverts under urban centers.

Earlier this year, onlookers cheered as Montana Gov. Brian Schweitzer declared, "Let 'er run," and a large bulldozer breached the Milltown Dam, a few miles upstream from Missoula, Mont. Today, the waters of the Clark Fork and Blackfoot rivers run free for the first time in 100 years.

Another measure of success: A large Superfund cleanup project at the rivers' confluence is underway to remove tons of contaminated sediment that flowed downstream from copper mines in Butte and stacked up behind the Milltown Dam, polluting the drinking water of nearby residents. The costs of such cleanups can be high, but the benefits can be enormous. Restoration work itself provides jobs for skilled laborers and professionals. The Milltown Dam removal currently employs about 80 people, ranging from heavy equipment operators to engineers and scientists.

Like the reclamation projects of the last century, today's restoration initiatives represent an investment in the future, with long-term benefits for both the environment and its human inhabitants. By recognizing the value of this work and encouraging it through more explicit public policies, we can ensure a healthier and more prosperous future for all. That is the heart of a new progressive movement for the Rocky Mountain West. sp

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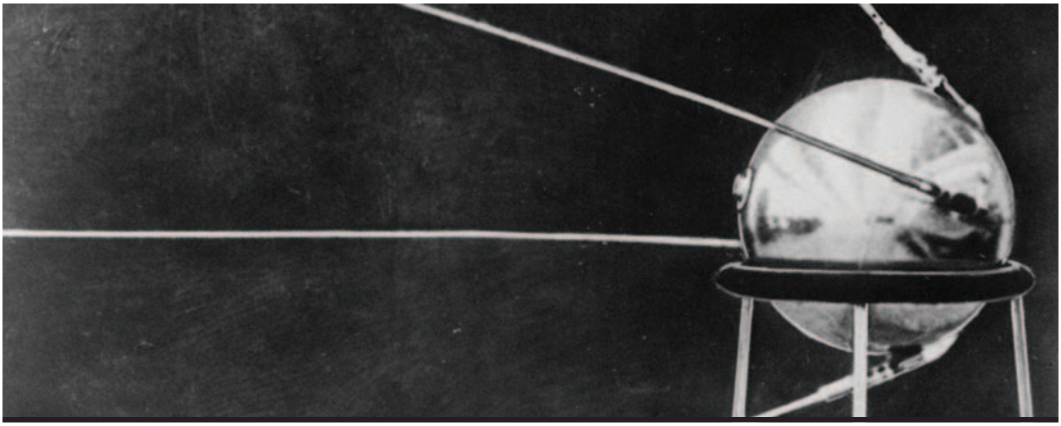
NEW FRONTIERS



AP PHOTO

# A New Scientific Resolve

## Reflecting Forward on Sputnik's 50th Anniversary

By Vinton Cerf

**REFLECTING FORWARD ON OUR** nation's incredible ability to respond swiftly to complex scientific challenges, one can't help but begin with the shock of the Soviet Union's Sputnik launch 50 years ago. Suddenly, there was a new star in the firmament, its radio signal sounding like the ominous ticking of a clock toward Armageddon. If the Soviets could put a satellite in orbit then they could potentially launch nuclear-tipped intercontinental ballistic missiles in the future.

Just over a decade later the United States mobilized the basic science, the requisite technologies, and the financial and policymaking wherewithal to carry Neil Armstrong and Buzz Aldrin to the Earth's Moon. This stunning sequence of events and actions spell out in forceful and compelling terms the ability of the United States to marshal its resources to respond to national and international challenges. That we were able to do so is an inspiring lesson that should be applied to the challenges we now face in the 21st century.

Fortunately for humankind, our nation's advanced science and technology can be harnessed to respond to a very different set of threats than those posed by the Cold War. Even better, all of humanity itself is our common ally in this quest.

Today, quicksilver globalization powered at unprecedented speed by the advent of the information technology revolution leaves our planet choking on the fumes of rapid global economic growth and all the attendant ills of global climate change. Yet these same forces transforming the global economy in myriad ways also enable each and every one of us to be part of the solution.

Modern communications technologies invite us to think of cooperation rather than competition as the venue for new ideas and new wealth. It is widely recognized that while material assets such as factories provided the leverage for the creation of value in the industrial age, information is the new coin of the realm. And unlike industrial infrastructure, which could benefit only one user at a time, access to information is not a zero-sum game.

As John F. Kennedy (the president who was arguably elected by Sputnik) liked to say, "A rising tide lifts all boats." As we look to solve global problems we need to take a more imaginative, less adversarial approach to generating the products and arrangements that will make for a more livable planet. Our national response to Sputnik 50 years ago should inspire us today to transcend national boundaries—moving beyond competition as the framework of human achievement.

Global climate change is a planetary threat that the United States cannot do less than meet head on with the same kind of determination and leadership that placed us on the Moon. Global warming is our 21st century Sputnik. Former Vice President Al Gore has been tireless and immensely persuasive in his efforts to draw attention to this problem. Yet it is time for scientists, technology leaders, financiers, and public policymakers to take the same kind of concrete, swift steps embraced by our country 50 years ago—steps that can result in a new flourishing of creativity and ingenuity emblematic of great scientific endeavors.

Remember, sweeping scientific inquiry informed by smart policymaking carried us to the Moon, but the many ancillary results of that mission are part and parcel of our world today. New materials needed for re-entry into the atmosphere and for protecting human life during space walks found their way into commercial products. Significant computing power was brought to bear in the design and planning of space systems and missions and the analysis of rocket engine performance.

Or consider the command and control of the complex Apollo missions. Computers for command and control led directly to the invention of the ARPANET and the succeeding Internet. Management practices for complex systems found their way from the space program into the private sector, enhancing productivity and scalability of enterprises.

Indeed, at age 15, and already a science fiction junkie, I would benefit directly from the enrichment programs stimulated in large measure by the Sputnik launch. Introduced to computers in 1958 via the Semi-Automated Ground Environment tube-based computer at System Development Corp. in Santa Monica, California, I found myself using computers at the University of California, Los Angeles while a senior in high school and taking every computing course I could at Stanford University as an undergraduate student.

In 1965 I went to work for International Business Machines Inc. as a systems engineer and returned to graduate school at UCLA where I ended up working on the ARPANET project funded by the agency that was formed in response to Sputnik. I graduated and joined the faculty of Stanford University and, together with Robert E. Kahn, designed the basic architecture and protocols of the Internet.

This led to my joining ARPA as a program manager and eventually principal scientist in the Information Processing Techniques Office that was founded in 1962 by J.C.R. Licklider of the Massachusetts Institute of Technology.

This confluence of events in my life (and in the lives of many other American scientist and engineers) is no accident. Fifty years ago the United States rose to the challenge. Similarly, resources dedicated today to the challenge of global warming will ensure innovation continues to flourish across our planet.

In fact, many of the steps that can be taken to respond to the serious dislocations global warming will cause make eminently good independent economic sense. The development of high mileage internal combustion engine cars, or alternative clean-energy vehicles such as hybrid automobiles or all-electric cars, would reduce pollution and dependence on oil imports. The research needed to achieve this objective could be led by the American automobile industry and even subsidized by a civilian equivalent to DARPA. And just imagine what other benefits would flow from a dedicated wave of research into lighter and stronger materials, more efficient and lighter weight batteries or fuel-cell systems, and alternative fuel sources.

The same multiplier effect holds for other scientific endeavors into a variety of green technologies, among them: reduced energy light sources; more efficient heating and cooling designs and technologies; better mass transit systems; higher speed and more widely available communication services to support working from home; more effective traffic control systems to reduce congestion (and wasted energy); improved desalinization methods to cope with the loss of fresh water from mountain snow pack and glaciers or underground aquifers; global power grids to transport electricity from areas of excess to areas of need.

Indeed, a post-Sputnik-like response to climate change would inevitably spur innovation in seemingly unrelated terrain brought on by global warming, such as preparing for the inevitable increase in diseases caused by the side effects of severe weather and storm surges. Moreover, successful results could become the basis for valuable international economic trade since the uses for these ideas are not bound to their domestic origins.

The National Science Foundation, for example, could accelerate the development of curricular material to emphasize science, mathematics, and engineering in the interest of responding to climate change. The Internet can be used to disseminate this material and to share information globally to speed the research that is needed. Prize programs could be established to encourage research and experimentation in areas of specific need.

Considering the consequences of not responding to this planetary challenge, it seems inescapable that the United States can and must take a leadership role. We consume more resources and generate more greenhouse gases per capita than any other country. Other countries may soon exceed, in absolute terms, our contribution to global warming, and it is in our best interest to develop alternative technologies and to share them widely.

We responded effectively to Sputnik, and this is even more important. We can do it again. sp

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*Vinton G. Cerf is vice president and Chief Internet Evangelist for Google.*

# UBIQUITY REQUIRES REDUNDANCY

## The Case for Federal Investment in Broadband

By Mark Lloyd

**THE UNITED STATES WILL NOT MEET** President Bush's goal of universal broadband by the end of 2008—not by a long shot. The number of subscribers to Internet services is growing faster than the adoption of "dial-up," yet for the most part these subscribers are not connected to the broadband technology Congress described in 1996 as a two-way communications service capable of high-speed delivery of data, voice, and video.

This failure to connect over half the country to advanced telecommunications service is not a technological failure. It is a 21st century public policy failure. In the 1990s, policies established by the Clinton administration to encourage public/private telecommunications partnerships, to connect schools and libraries to the World Wide Web, and to allow competitive service providers onto the networks of the local telephone monopolies all sped up the deployment of broadband around most of the nation. These policies were either deliberately abandoned or hampered by the Bush administration.

The increasing noise from Washington about the lack of a U.S. broadband policy obscures the fact that a policy choice was made by the Bush administration to rely entirely on "market forces" to determine how and where advanced telecommunications services would be deployed. That policy has failed.

The goal of federal investment in broadband should be first and foremost to ensure our ability to respond to threats to our homeland security and to natural disasters. And the result of administration neglect, industry intransigence, and the incompetence of a Federal Communications Commission apparently "captured" by the industry it is supposed to regulate has left the American people and most policymakers with no clear idea where broadband services are deployed in the United States.

There is no credible dispute that the United States has fallen behind Canada and France and Japan and a dozen other industrial countries in broadband deployment.[2] Americans are not more adverse to new technology compared to our neighbors to the north or our friends overseas. The difference is that these countries have moved ahead of the United States after having adopted one version or another of U.S. telecommunications policies established in the mid-1990s.[3]

In addition to leaving America less competitive in a global economy, this failure has left the nation vulnerable and ill-prepared for real threats to our national security—the rationale behind the initial U.S. government investment in the development of the Internet.

The American invention of the Internet, of course, was preceded by hefty scientific investments beginning with the Eisenhower administration for military purposes. In fact, the Internet developed despite "market forces" dominated by the not-so-invisible hand of the Bell telephone monopoly. While the development of the Internet has certainly benefited from global market forces, the "free market" blinders that prevent present-day U.S. policymakers from seeing beyond the interests of corporations must be removed. While Reagan-era Republicans seem to don their blinders with greater pride, this is not a partisan issue. It was, after all, Vice President Al Gore who insisted that the "information superhighway" would not be built the way the U.S. highway system was built, but would instead be financed by private enterprise.[4]

If the United States is to catch up with other developed and developing nations, however, we must look beyond even the abandoned policies of the Clinton era and begin to move with greater urgency and resolve to address pressing disaster response and defense needs. After all, the attacks of 9/11 and body blow of Hurricane Katrina highlight for all but the most doctrinaire advocates of free markets that there is an exceedingly strong case for direct government investment in the deployment of advanced telecommunications services to build a safe, strong, and resilient America.

The goal of federal investment in broadband should be first and foremost to ensure our ability to respond to threats to our homeland security and to natural disasters. Directly connected to this goal is the availability of advanced telecommunications services in our health care and educational systems—

the modernization of which is key to our nation's ability to respond to threats to our national security and public safety immediately and over the coming decades. Without ubiquitous broadband our first responders could be crippled by the lack of effective communications in the event of a terrorist attack or natural disaster. Similarly, our educational institutions need to be able to communicate quickly and effectively in case of a pandemic, as well as conduct R&D on all of the technologies needed to maintain our nation's national defense and public safety.

In meeting these goals, federal investment should make certain that the U.S. communications infrastructure is continually upgraded, robust, redundant, and able to withstand multiple threats and uses. The public should not be left to rely on any one technology, but rather on multiple technologies—each able to operate with the other, and each able to serve important needs if the other technologies are destroyed or compromised. Market forces will not guarantee this result.

## INFRASTRUCTURE FOR A STRONG AND SAFE AMERICA

In small rural towns, in the crowded barrios and ghettos of urban U.S. cities, in those places where financial institutions are not yet convinced they can get an adequate return on investment, Americans do not have access to the communications networks they will need to keep them safe in the future.[5] It is no coincidence that these same places hold our nation's toxic waste dumps, our chemical plants, and our seaports and airports, yet we do not have the ability to communicate most effectively where we are most vulnerable.

The Department of Defense has long been provided almost all the communication resources it needed to protect American interests overseas. What has been too often forgotten is the importance of equipping all Americans with the ability to participate effectively in the national defense effort at home. Americans take pride in assisting when their communities are under attack or threatened by a natural disaster. A concerted effort must be made to equip all Americans so they are able to communicate effectively when confronted by catastrophe.

President Eisenhower understood the value of a robust transportation system at home to sustain national unity and to promote defense needs. In announcing the new interstate highway system, Eisenhower called the effort "the National Defense Highway System," citing his direct experience with a problem-laden military convoy from Washington, D.C. to San Francisco he took in 1919.

Despite the squabbles of some local government and business leaders who fought against a federal highway system, Eisenhower was convinced that America could do better. As Richard Weingoff reports in his excellent history of the interstate system, when Vice President Richard M. Nixon delivered an address before a 1954 conference of state governors at Lake George, NY, reading from Eisenhower's detailed notes, he declared that the U.S. "highway network is inadequate locally, and obsolete as a national system."

Nixon then recounted Eisenhower's convoy and then cited five "penalties" of the nation's obsolete highway network: the annual death and injury toll, the waste of billions of dollars in detours and traffic jams, the clogging of the nation's courts with highway-related suits, the inefficiency in the transportation of goods, and "the appalling inadequacies to meet the demands of catastrophe or defense, should an atomic war come."[6]

If America is to be ready "to meet the demands of catastrophe or defense," all Americans need access to advanced telecommunications services in the 21st century, just as they needed access to an advanced highway system in the 20th century. But as the 9/11 Commission noted in its report, the United States is not ready for a national emergency. And as every comprehensive analysis of the tragedy of Hurricane Katrina revealed, we are not prepared to handle a major natural disaster. Both of these experiences highlight the importance and the multiple failures of U.S. communications services as warning systems or as systems to allow for the coordination of first responders.[7]

### *Command and Control vs. National Leadership*

A standard complaint of conservative defenders of the current telecommunications regulatory system regarding communications policy focuses on the supposed "command and control regulatory policies" of the federal government.[8] They argue that the heavy hand of regulation stymies the roll out of advanced telecommunications networks across the nation when in fact the tendency of the federal government historically is to exercise this "command and control" on behalf of the communications industry itself.

The result of this regulatory protection of different bits of the telecommunications industry leaves the United States with balkanized communications capabilities. If the prevention or response to the terrorist attacks on 9/11—when New York City police, fire, and rescue workers could not communicate with each other amid the chaos and carnage of that awful day—or the prevention or response to the failed levees overwhelmed by hurricane Katrina demonstrated anything, they demonstrated the need for better command and control.[9]

Indeed, in the debate over communications policy, the term "command and control" is little more than a right-wing slogan. Outside of military operations this phrase has never accurately described either the policymaking process or the execution of policy in the United States. Even the federal highway system so important to Presidents Roosevelt, Truman, and Eisenhower for military purposes, was the product of a contentious federal–state partnership.

Still, there is no question about the importance of federal vision and leadership and funding.[10] The importance of strong federal engagement in the development of the national highway system is beyond dispute. The same can be said of the importance of federal leadership in the U.S. space program, which led to the U.S. satellite industry, as well as federal leadership in the Defense Advanced Research Projects Agency, which spurred the research behind the Internet.

> How our country's critical communications infrastructure is deployed is entirely determined by private industry.

Perhaps the most direct corollary to the national highway system in the U.S. telecommunications arena is the National Communications System. The NCS began after the Cuban missile crisis. Communications problems between and among the United States, the Soviet Union, and other nations helped to create the crisis. President Kennedy ordered an investigation of national security communications, and the National Security Council recommended forming a single unified communications system to connect and extend the communications network serving federal agencies, with a focus on interconnectivity and survivability.

The NCS oversees wireline (Government Emergency Telecommunications Service) and cellular service (Wireless Priority Service).[11] The NCS is now part of the Department of Homeland Security's Preparedness Directorate, and despite the increased attention to the communication needs of first responders on September 11, 2001, NCS failures and inadequacies were made obvious after Katrina.[12] In New Orleans, police officers were forced to use a single frequency on their patrol radios, which "posed some problems with people talking over each other," explained Deputy Policy Chief Warren Riley at the time. "We probably have 20 agencies on one channel right now." And with little power to recharge batteries, some of those radios were soon useless.

In southern Mississippi, the National Guard couldn't even count on radios. "We've got runners running from commander to commander," said Maj. Gen. Harold Cross of the Mississippi National Guard. "In other words, we're going to the sound of gunfire, as we used to say during the Revolutionary War."[13] As Sen. John Kerry (D-MA) said: "This is a further demonstration of our inadequate response to the 9/11 Commission's recommendations and other warnings about the failures in our first responders' communications systems."[14]

How can these obvious communications failures still leave the United States groping for an adequate response? One of the biggest challenges we face is the tendency to see national defense and emergency needs regarding communications as separate and unrelated to the communications needs of the American public. The NCS has established an elaborate set of protocols that make government communications a priority over what is called the public switched network. Federal, state, and local governments pay substantial fees to use this communications network. But the determination over how that network is upgraded and deployed is entirely determined by private industry.

We cannot have a robust, survivable, interoperable communications system that protects the public if the public is treated merely as a mass of consumers and not as an integral part of national defense and emergency response. The U.S. public remains vulnerable because our communications infrastructure is too often viewed only as a private business. Katrina and 9/11 remind us that access to advanced telecommunications service is a public need. We need national leadership to remind us of this, and insist on policies that address public needs.

## ADVANCED TELECOMMUNICATIONS CAPABILITY IN THE 21ST CENTURY

In the 1996 Telecommunications Act, Congress indicated that advanced information and communication technology, or ICT for short, should provide the ability to send and receive data, voice, and video. Today, advanced ICT means the ability to send and receive high-definition video in real time, something that requires massive telecommunications power if the goal is for everyone to be able to do so. Further complicating this goal is that in emergency situations communications systems become easily overloaded as people rush to their phones to check on loved ones.

In the case of an emergency or national disaster we need a capacity far greater than the market would support for even heavy shopping days. A starting point would be symmetrical speeds (both download and upload capability) of 10 gigabytes per second. Today, speeds of that magnitude are available only at the most important point-to-point interchanges of the Internet backbone or between dedicated military, financial, educational, or scientific institutions. Both fiber and robust wireless services have the potential to deliver these speeds in both directions.

But the construction of one or even two robust communications pipelines into police stations or military posts would still leave the United States vulnerable. The sole reliance on only one or two sources of communications creates an inviting target and, at the very least, creates the potential for deadly communications bottlenecks. Telecommunications businesses won't help us solve this problem. At their best, they work to create greater efficiency by eliminating redundancy. At their worst, they work to eliminate any and all competition so that even efficiency doesn't matter.

When reliability is essential, redundancy is highly valued. When lives are at stake, establishing alternative systems that can do as good a job as any designated primary system is routine. And while our policymakers speak of competition—sometimes even embracing competitive communications infrastructures that might lead to alternative "consumer" choice—policymakers rarely seem to understand that alternatives are essential to national defense and emergency preparedness.

Redundancy is so essential to public safety and national security that where private industry refuses to create these alternatives government must do so.

In fact, redundancy is so essential to public safety and national security that where private industry refuses to create these alternatives government must do so. Safety engineers consider redundancy a critical ingredient of creating a system with a high probability of safety. In the commercial aircraft industry, for example, pilots and passengers are assured of safety in part because redundant equipment, including engines and sensors, are required by government regulation.

In addition to redundancy, it is vital that the different systems and the equipment operating over these communications systems be interoperable. One unfortunate result of relying on private competition is the tendency of competitors to develop systems which do not permit interoperability. A key failing of emergency response after 9/11 and Katrina was the lack of interoperable communications equipment.[15]

Many of the problems of interoperability are the result of turf wars and not equipment limitations. Federal policies to override local turf wars are essential. The Department of Homeland Security has made it a priority to solve the range of problems related to interoperability.[16] But again, interoperability must not be limited to operation over one infrastructure, but must cross all relevant communications platforms. Phones and computers must operate over wireline and wireless infrastructure, including competing wireline and wireless networks. Interoperability is a vital component of emergency service and a modern communications network. Closed "private" broadband networks stifle not only innovation and service competition, they also limit the ability of all Americans to participate effectively in response to natural disaster and terrorist attack. If the United States is to compete effectively in a global economy and defend itself against global terrorist threats, then it must take advantage of the unique opportunities only possible with an open network.

Federal law should require that all broadband networks are open to the attachment of any equipment the user chooses—so long as it does not harm the technical operation of the broadband network. In addition, federal law should require broadband networks to be open to other information service providers and accessible to other networks, except for restrictions related to vital law enforcement or for network management.

### *Investing in Multiple Technologies*

Our nation's wireline infrastructure is inadequate to meet 21$^{st}$ century needs. The old telephone network is simply incapable of delivering the bandwidth to meet the emergency needs of today and the future. While efforts have been made to upgrade the relatively more modern cable infrastructure, there are too many rural communities where the cable system has not upgraded to provide digital service. Even in our major metropolitan areas, gross deficiencies are self-evident.

The strain on the existing telecommunications infrastructure was obvious as call after call was blocked during 9/11. But this strain is obvious to anyone who regularly uses either the Internet or regular cell phone service in a major metropolitan area in the United States. The concerns that the Internet as presently constructed simply will not bear the amount of use projected over the next five years are longstanding. While more sophisticated filtering and better emergency protocols may address this problem in the short-term, the strain on the nation's telecommunications infrastructure will only increase as the call for greater bandwidth for video over the Internet increases.

If meeting the communications needs of first responders or panicked parents were simply a matter of "market forces," then one would be tempted to applaud the telephone and cable companies for squeezing as much profit as possible out of old technologies. But the challenge of communicating in an emergency should not be held hostage to even legitimate profit-seeking demands of private investors.

In brief, the nation should be investing in the deployment of fiber, powerline, wireless, and satellite communications technologies. The combination of these technologies would ensure robust and ready communications services in case of a national emergency. What's more, these technologies are readily available for roll out, as we will detail below.

## OPTICAL FIBER

The most promising single technology that could deliver advanced telecommunications connectivity to homes and offices everywhere is optical fiber, a thin glass or plastic line designed to distribute light. Optical fiber is distinct from the electricity that distributes communications through copper telephone wires or coaxial cable. The light in optical fiber permits transmission of digital data over longer distances and at higher rates than other forms of communications.

Fiber optic products have been used for several decades in a variety of defense technologies designed for air, sea, ground, and space applications. During the high technology boom of the 1990s many privately held companies and public corporations built out vast fiber optic networks even as telecommunications companies beginning in the early 1990s began to upgrade their networks to incorporate fiber technology. Yet only one large U.S. company, Verizon, has extended optical fiber to the home.

The immediate reaction from Wall Street to Verizon's plans was pessimistic. Verizon's stock value in 2006 dropped and investors pressured the company to scale back deployment or abandon the investment in fiber to the home altogether. The reason: Investors saw little reason to back Verizon's expensive ($23 billion) proposition.[17]

Nevermind that over time Verizon's emphasis on delivering video entertainment alongside other telecommunications services so the company could compete with cable is now increasingly viewed as smart forward-thinking investment strategy. Unfortunately, Verizon's service areas are largely densely populated urban areas, and Verizon's rural customers are not likely to get fiber anytime soon. Other telecommunications companies, including AT&T and smaller, regional players, have no plans to provide their customers with fiber optic service to the home.[18] Again, the emphasis on market priorities, forward thinking or not, does not serve the goal of protecting Americans with the best communications service available in case of an emergency.

There are municipalities, however, that have deployed optical fiber networks with the expressed intent of improving the communications capability of emergency workers. One example is Arlington County, Virginia, just across the Potomac River from Washington, D.C. Arlington firefighters were the first to respond on September 11, 2001, when the Pentagon was attacked by terrorists. Beginning with its 10 fire stations in January 2002, by June 2002 all 40 county sites were connected to a fiber network. In 2005, Arlington extended the network to the nearby city of Alexandria, to facilitate inter-agency collaboration.[19]

These are the kind of public investments that federal, state, and local governments all need to make in tandem with the private sector to ensure that households and offices are all connected to the most readily available form of high-speed telecommunications. Ubiquitous broadband via fiber optics is the best first step that could be made by such a public/private partnership.

## POWERLINE COMMUNICATION

Broadband over power lines, known as BPL by industry insiders, is a promising technology that would make use of the extensive electrical power grid infrastructure to communicate digital signals. BPL, however, still has some kinks to be worked out. Both the electric grid and the home create what engineers call a “noisy” environment. Every time a device turns on or off, a pop or click is introduced into the line.

Indeed, BPL has developed faster in Europe than in the United States due to differences in power system design philosophies. Large power grids transmit power at high voltages to reduce transmission losses, and transformers that are near the customer reduce the voltage. Because BPL signals cannot pass through transformers, repeaters must be attached to each transformer. In the United States, a small transformer typically services a single house or a small number of houses. In Europe, it is more common for a larger transformer to service up to 100 houses. Delivering BPL over the power grid of a typical U.S. city will require many more repeaters as compared to a typical European city.

Despite these challenges, BPL in the United States is on the rise, with about 6,000 BPL subscribers nationwide as of 2006.[20] According to the United Power Line Council, commercial deployments are up slightly, from six in 2005 to nine in 2007. Trial rates, however, have fallen from 35 in 2005 to 25 in 2007.[21]

An indication of a possible increase in BPL penetration, however, came in 2007 when DirecTV announced that it was getting in on the BPL market. In a deal with Current Group, DirecTV plans to provide BPL service in the Dallas-Fort Worth and Cincinnati areas with a potential for much broader rollout. Not to be out done, Oncor, a subsidiary of Dallas power company Energy Future Holdings Corporation—formerly TXU Corporation—has started to deliver BPL service and it recently passed 108,000 customer deployments, less than five percent of its goal.[22]

The rise in BPL deployment can also be traced to steps the FCC took in 2006 to support the technology by reaffirming an earlier decision that BPL providers have the right to provide data access using power transmission lines so long as they do not interfere with existing radio service. Still, opponents of BPL, including the aviation industry and the amateur radio community, have continued to voice the strongest concerns over the issue of possible interference with radio communication,[23] though there is some dispute among experts over the degree to which electricity over BPL actually “leaks” and thus interferes with an electromagnetic wireless signal.

In a further boost, the FCC classified BPL-enabled Internet access as an information service, rather than a telecommunications service, in November 2006. According to the FCC, “The order places BPL-enabled Internet access service on an equal regulatory footing with other broadband services, such as cable modem service and DSL Internet access service.”[24] According to Joe Marsilii, president and CEO of BPL equipment maker and integrator MainNet Powerline Inc., 70 percent to 80 percent of the nation’s electrical grid will be equipped with BPL in five to eight years.[25]

This kind of rollout of BPL services, however, will not occur without a coherent policy advanced by those federal agencies responsible for keeping America competitive and secure. BPL could easily become the second ubiquitous source of broadband to all houses and offices with a plug. With only a few technology hurdles to clear, and with FCC regulatory clearance already evident, BPL through a public/private partnership could become available swiftly.

## WIRELESS BROADBAND

As anyone who has attempted to carry on cell phone conversations in New York or rural America will attest, reliance on the most prevalent wireless technology in America would be misplaced.[26] Cell phones are no less ubiquitous in big American cities than they are in London or Taipei or Toronto, but somehow cell phones seem much more reliable in other countries.

Coverage problems in the United States result from the lack of cell phone infrastructure—towers and repeaters—necessary to sustain a large number of users in the variety of locations. The infrastructure problems are directly tied to two factors. First, the costs to build that infrastructure at present outweigh the commercial benefit, which is the profit the telecommunications companies and their shareholders think they can realize. Second, because cell phone service is seen only as a commercial need, there is little public will to assist in supporting the cost of this infrastructure development by allowing, mandating, or helping to finance the build-out of towers and repeaters.

Coverage problems also result from the limited propagation characteristics of the spectrum set aside for cellular service. Most cell phone use in the United States is based on dated technology.[27] Advanced digital Internet protocols make possible voice, data, and video communications over mobile networks. Third-Generation or 3G broadband has been deployed effectively in the United Kingdom, Germany, Japan, and other countries, but the United States lags behind.[28]

The creation of a next generation wireless broadband network is an important public policy goal. The public safety benefits of reaching this goal justify significant federal funding to subsidize the development of such a network. One proposal is that the funding of a 3G public safety network could come by redirecting the billions of dollars designated to the federal government's wireless network project—estimated between \$5 billion to \$10 billion—and which will only serve a limited number of federal agencies.[29]

The focus, however, should not be on any one technology, but rather on the full funding of a public safety network that utilizes wired and wireless infrastructure. The establishment of a public safety network can serve as a strong starting point for the development of a next generation network for commercial purposes. A public safety network, however, should not be held hostage to commercial interests.

The emphasis on market priorities does not serve the goal of protecting Americans with the best communications service available in case of an emergency.

Federal allocation of spectrum must be revised to allow for the deployment of advanced wireless technologies. Licenses for all current analog radio and television broadcasting must be revoked, after which at least 25 percent of this spectrum should be set aside for public safety purposes, and half of the "vacant" spectrum should be reserved for temporary experimental applications with a priority placed on those applications that serve public safety, health care, or educational institutions.

### WI-FI AND WI-MAX

Wi-Fi is a digital wireless communications technology. The brand is owned by the Wi-Fi Alliance, a consortium of companies that have agreed to a set of interoperable products based on a standard (802.11) set by the Institute of Electrical and Electronics Engineers. Though the Wi-Fi Alliance apparently originally intended the name to mean "Wireless Fidelity," later statements from the consortium suggest the name is not an acronym or abbreviation.

Wi-Max is an acronym for "Worldwide Interoperability for Microwave Access." This was adopted by the Wi-Max Forum in 2001. Wi-Max adheres to the so called IEEE 802.16 standard and allows for higher speed networking across much wider geographic distance than is currently possible with Wi-Fi. Both Wi-Fi and Wi-Max in the United States face the technical challenges of limited spectrum allocation, particularly when compared with Europe.

As of mid-2007 there were over 400 counties and municipalities with wireless networks. These networks are used for applications ranging from reading meters to managing traffic and providing Internet access. Most municipalities contract with private companies to build and operate the network, and understandably the private industry is primarily concerned about profit. Therefore, in addition to the technical challenges in the United States, there are substantial difficulties with the business model.

Because of both the technical and business challenges, large-scale municipal wireless projects are flopping in big cities all across the United States. The problems arising in Houston, Chicago, St. Louis, Philadelphia, and San Francisco are for the most part very similar: the infrastructure (nodes and towers) was not in place, and when private companies were contracted to build the infrastructure, raising public money was difficult. Plans to migrate to public from private service were complicated by the fact that the slower and less reliable Wi-Fi connections are not able to compete effectively against incumbent wired (cable or DSL) Internet providers. As one reporter put it:

> *This summer was hard on urban Wi-Fi. Exhibit A: the extreme corporate shake-up at Earthlink, one of the biggest names in municipal wireless. In the same few days, the Atlanta-based Internet provider abandoned its much-heralded proposal to build San Francisco's wireless network, faced a $5 million fine from Houston for missing a contractual deadline in rolling out that city's network, and announced it would shed some 900 jobs—half of its staff—including the company's head of municipal Wi-Fi. In St. Louis, a $12 million plan stalled out this summer when AT&T and the city couldn't untangle an electricity snarl… That plan is on hold indefinitely. With these signs of the industry buckling, Chicago officials backed off their plans to install a city network after failing to reach an agreement with either of the competing wireless providers.*[30]

The success stories of municipal Wi-Fi come from small towns. In St. Cloud, Florida, a truly citywide municipal Wi-Fi network exists at no cost to residents. Mountain View, California has a citywide wireless network owned by Google with free service to residents. Both these networks operate over relatively small geographic areas: Mountain View is 14 square miles; St. Cloud is 12 square miles. Of the 400-plus American cities and counties attempting municipal Wi-Fi, most cannot offer it for free. There are currently only 92 cities or towns with active municipal Wi-Fi networks.[31]

The telecommunications industry nonetheless argues that the involvement of municipalities creates unfair competition for private organizations because of their ability to use public assets. The industry also argues that municipal governments do not have the necessary expertise to operate or maintain the technology and anyway should not be "picking winners" in a competition among technological alternatives.[32]

Preoccupation with these industry concerns largely obscures the needs of public safety and emergency response. While neither Wi-Fi nor Wi-Max will address all the communication needs of local communities, the establishment of these systems can help fill in the deployment gaps and assist in providing the important redundancy demands of emergency communication. Fixed microwave wireless communication systems can also help fill in critical gaps.[33] The real problem is the tendency to look for easy answers rather than implement comprehensive solutions that should include Wi-Fi and Wi-Max. Federal leadership is needed to push forward a rationale for public investment that puts a priority on safety and emergency response.

### SATELLITE BROADBAND

Satellites in geostationary orbit can relay Internet speeds of about 0.5 megabits per second to the user. But satellite broadband typically allows for only 80 kilobits per second from the user. In many rural areas this is a substantial increase over what is typically available. Although DirecTV and a few others have invested in making satellite broadband service a commercial competitor, it suffers from serious competitive disadvantages. Bad weather and sunspot activity can cause unreliable signals and dropouts. Applications such as virtual private networks and voice over Internet protocol, or Internet telephony, are discouraged or unsupported. And most satellite Internet providers abide by a Fair Access Policy, limiting a user's activity, usually to around 200 megabits per day.

Perhaps the greatest commercial disadvantage, however, may be the delay that results from the 44,000 miles a signal would need to travel from the user to the satellite company. This delay results in a connection latency of 500 to 700 ms, as compared with a latency of 150 to 200 ms typical for terrestrial Internet service providers.

Still, new technology has decreased the weight and size of satellite antennae and receivers, which combined with computer tracking devices makes it easier to send and locate satellite signals. And perhaps the biggest advantage of satellite broadband, particularly for emergency use, is that it can be established very quickly on a mobile unit that can avoid an attack or be rushed to the scene of a natural disaster. Fixed towers and telecommunications conduits necessary for wired or terrestrial wireless services are much more vulnerable to attack or natural disasters.[34]

All these communications technologies—satellite broadband, Wi-Fi and Wi-Max, wireless broadband, power-line communications, and optical fiber networks—are available for local, state, and national government to warn and protect citizens. It is not a matter of choosing one or the other, but intelligently investing in all these technologies and engaging in research to develop more. Government protection of the U.S. telecommunications industry should take the form of ensuring that industry is protected in case of an attack or natural disaster, it should not take the form of protecting industry profit at the expense of national security. America needs a robust communications system for emergencies the nation will surely face in the future.

## WHERE ADVANCED ICT INFRASTRUCTURE SHOULD BE DEPLOYED

All government offices, health care centers, primary and secondary schools, military, police and fire, and emergency responders need access to advanced information and communications technology to prepare for and respond effectively to natural disasters and terrorist attacks. Federal and state governments may bicker over their relative access to advanced ICT, but there is little disagreement over the need for access. Similarly, while there are disputes on the edges there is a general consensus that police, fire, and emergency responders need this access.

But there are other institutions in this country that require ubiquitous broadband access in order to help our citizens in times of crisis, the two most critical sectors being educational and health care institutions.

### *Health Care Centers*

Health care centers face extraordinary burdens during and after emergencies. The victims of natural disasters or other catastrophes require medical attention, as do the emergency responders who risk their lives. The ability to diagnose and monitor patients, to access patient records, and to communicate with pharmacists is increasingly dependent upon reliable communications systems within and beyond the hospital.

The absence of robust and redundant communications systems in our community health care facilities puts at risk not only patients but those who risk their lives to keep the rest of us from having to enter the hospital. In addition, advanced telecommunications systems have proven to be effective in providing access to medical expertise even over great distances.

A cardiac patient in a small military hospital in Guam, for example, was able to undergo a life-saving heart operation supervised by an expert doctor located 3,500 miles away at Tripler Army Medical Center in Honolulu. The surgery was relatively routine for Dr. Benjamin Berg, who was able to dictate the procedure to a less experienced colleague, monitoring every move and heartbeat with a high-resolution video camera and instant sensor gathering data from the catheter as it was slid carefully into the right chamber of the patient's heart.

"The real-time information requires a continuous broadband connection," Berg said. "The delay in the transmission of data about pressure inside the heart would be unacceptable."[35] Imagine doctors being able to help patients remotely as the health care centers in New York and the Gulf Coast were inundated.[36]

The example cited above of the surgeon in Honolulu supervising an operation in Guam is but one of the remote care practices engaged in by the Veterans Administration system. The VA also works with the Alaska Federal Healthcare Access Network, which links nearly 250 sites including military installations, Alaska Native health facilities, regional hospitals, small village clinics, and state of Alaska public health nursing stations to provide various healthcare services using high-speed broadband services including satellite broadband.

A VA study of a remote monitoring program demonstrated a 40 percent cut in emergency room visits and a 63 percent reduction in hospital admissions. A separate Penn State University study estimated that remote home health monitoring for diabetes patients cut costs for hospital care by 69 percent. According to Jon Linkous of the American Telemedicine Association, "Broadband Internet access to hospitals is becoming a critical tool in the delivery of medical services."[37]

In addition to providing the communications infrastructure to local health care facilities, it is vital to increase support for both the National Institutes of Health and the Center for Disease Control. NIH has long demonstrated its importance in emergency and disaster readiness. One notable program is the University of California, San Diego and the California Institute for Telecommunications and Information Technology's $4 million WIISARD (Wireless Internet Information System for Medical Response in Disasters) project, which is funded by NIH's National Library of Medicine.

The WIISARD project allowed the San Diego Metropolitan Medical Strike Team to bring together scientists and engineers from the California Institute for Telecommunications and Information Technology with local and state police, SWAT, fire, HazMat, and other first responders. In a simulation in 2005, the team was able to test the prototype of a video system that allows medical personnel to view a 3D virtual environment generated by a live video stream.

In another new technology demonstration by the WIISARD project, first responders were provided wireless personal digital assistants, or PDAs, outfitted with software to help them keep track of victims' locations and triage status, capturing important medical data at the point of triage and transmitted that immediately back to hospitals and a command center using a Wi-Fi network. According to Jacobs School of Engineering computer science and engineering professor Bill Griswold, San Diego's Metropolitan Medical Strike Team "has realized that law enforcement is an integral part of medical disaster response, and to better coordinate that, they anticipate that technologies like this can be useful in communicating from law enforcement to medical responders without distracting law enforcement from their duties."

Griswold adds that "we've also had some interest from SWAT officials because these technologies would allow SWAT teams to communicate information silently back to their commanders. Currently they have to use hand signals or radios, Broadband Internet access to hospitals is becoming a critical tool in the delivery of medical services.

both of which put them at risk from exposing their positions." Continued NIH funding to support this work is critical in keeping the nation safe and prepared for emergencies.[38]

Similarly, but on a national scale, the Center for Disease Control and Prevention is an essential health care institution in emergencies, particularly in an age of biological weapons and biohazards that spread as a result of natural disasters. Whether it is containing the threat of anthrax or limiting the spread of waterborne human disease, it is essential for the CDC to have effective communications capability in the first hours of an emergency.[39]

### *Educational Institutions*

In 1957 America rested assured of its status as a singular world power, convinced of her superiority on every front after the victory of World War II, after the development and detonation of an atom bomb, and after the resurgence of the economy that followed the Great Depression and allowed the United States to contribute to the rebuilding of Europe. America could finally rest, and rest easy. And then, in October of that year, America's rest was rudely interrupted by Sputnik.

The Soviet Union's launch of an orbiting satellite haunted the American dreamscape with the sudden threat of communist missiles raining down from the skies, which sent school children under their desks to duck and cover. The Director of Development for the Army Ballistic Missile Agency at the time, German rocket scientist Werner von Braun, testified before a subcommittee of the House Committee on Education and Labor:

> *Modern defense programs… are the most complex and costly, I suppose, in the history of man. Their development involves all the physical sciences, the most advanced technology, abstruse mathematics and new levels of industrial engineering and production. This… require[s] a new kind of soldier, who may one day be memorialized as the man with the slide rule… It is vital to the national interest that we increase the output of scientific and technical personnel.*[40]

Sputnik's wake-up call led directly to the establishment of the Defense Advanced Research Projects Agency, or DARPA, which is credited for inventing the Internet. It also led directly to the passage of the 1958 National Defense Education Act. The NDEA allocated approximately $1 billion in funds to supporting research and education in the sciences through 1962.[41] The connection between education and defense could not be clearer.

Of course, educational institutions must have robust communications systems to warn and protect teachers and students. But to focus solely on American schools because they might be targets holding our children, our most valuable assets, would be to miss the lessons of the past. Our schools, whether at the elementary or at the graduate school level, must have the most advanced information technologies available if we are to develop the minds we will need to protect ourselves and find solutions to the various complex challenges in an increasingly complex world.

U.S. students and teachers must have ready access to the most advanced information technologies available. To deny this access because a government investment may challenge the interests of private corporations misses the larger point that not doing so will rob those corporations of the very minds they need to stay competitive. To deny access to this technology may rob the nation of the resources it needs to save itself.

The importance of making advanced communications technology available to schools and students has been the subject of hundreds of reports over the past 50 years. Information technology leaders in higher education were actively engaged in planning and deploying the networks that led to the formation of what many think of as the original Internet, the NSFnet of the late 1980s, along with successful efforts to generate congressional support for scientific and academic networks, leading to the High Performance Computing Act of 1991, and the National LambdaRail effort to build an all-optical, facilities-based network for leading edge science and research.

The value of advanced broadband infrastructure is apparent in fields such as astronomy and genomics, but e-learning has barely scratched the surface of its potential.[42] Students, particularly those who are not living at school, continue to have difficulty accessing broadband service. Undeterred, conservatives in the telecommunications industry continue to attack the Universal Service Fund program established by the 1996 Telecommunications Act, and have sought to undermine its effectiveness since its inception.

Yet the effectiveness of this program is undeniable. In 1998, at the beginning of the implementation of the USF program, only 14 percent of public school instructional classrooms were connected to the Internet; as of 2003, classroom Internet access was at 93 percent.

Nearly all public library outlets today are now able to offer some Internet access. Yet in each funding year since 1998, requests for E-Rate discounts vastly exceed the $2.25 billion made available. Despite the clear need and success of Universal Service, the Bush appointees at the FCC have threatened support for the fund by excluding cable companies providing advanced telecommunication services from the requirement of a universal service contribution.

What's more, in 2004 the FCC suspended the E-Rate program for three months. The ostensible reason: The FCC determined that the Antideficiency Act, which bars federal agencies from obligating funds without adequate cash on hand to cover those obligations, applied to the E-Rate.

The Universal Service Fund subsidizes the schools and libraries, the poor (Lifeline and Link-Up), rural telecommunications services, or telemedicine applications. When the Bush administration limits contributions and stalls funding it is heading in exactly the wrong direction. All Americans should have access to advanced telecommunications services whether they are poor, living in high-cost rural or urban areas, or living on fixed incomes.

Citizens remain our first line of defense and response in a natural disaster. If Americans are not connected, deployment will make little difference. USF support for advanced telecommunications services are clearly needed if all Americans are to be connected. A renewed commitment and a national broadband policy that puts universal access at the top of the list are past due.

## CONCLUSION

The United States needs to move forward in a coherent fashion to deploy advanced telecommunications infrastructure, but not because we want to be number one. We have vulnerabilities at home that need to be addressed with some urgency. The possibilities resulting from the synthesis of powerful networks, computers, and databases have been the subject of a variety of blue ribbon panels, most notably the U.S. National Science Foundation report on cyberinfrastructure in 2003.[43] Five years later another panel is in order, with recommendations ready for a new administration and a new Congress.

The first work of such a panel should be to get accurate information on the deployment and capability of the various communications networks now operating in the United States. This paper has discussed a range of basic principles to meet the ends of national security and response to natural disasters. Those principles include:

- Robust networks capable of symmetrical speeds of 10 Gbps
- Redundancy
- Interoperability
- Network neutrality

We have a wide range of technologies available to communicate effectively. We should not choose between satellite broadband, Wi-Fi and Wi-Max, wireless broadband, power-line communications, and optical fiber networks—all of these technologies should be invested in along with new developing technologies to protect our defense and emergency needs at home. Because our citizens are our first line of defense or response, we need to make a commitment to universal service regarding advanced telecommunications services for all Americans.

As President Eisenhower said in 1955, "Our nation is sustained by free communication of thought and by easy transportation of people and goods." Our dependence on communications systems makes them more critical now than ever before. And as we pulled together and committed to the development of highways, satellites, and schools to win the Cold War, we must pull together now. sp

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**BIOSECURITY**

AP PHOTO/KENNETH LAMBERT

# Dual Use Dangers

## Biotechnology and Global Security Are Intertwined

By Jonathan Tucker

**IN A CAUTIONARY MESSAGE** to the world just before his retirement, then U.N. Secretary-General Kofi Annan said that as biological research expands and advanced biotechnologies become increasingly available, the associated safety and security risks will increase exponentially. "When used negligently, or misused deliberately, biotechnology could inflict the most profound human suffering—ranging from the accidental release of disease agents into the environment to intentional disease outbreaks caused by state or non-state actors," he warned. "Soon, tens of thousands of laboratories worldwide will be operating, in a multi-billion dollar industry. Even novices working in small laboratories will be able to carry out gene manipulation."[1]

Annan then pointed out that the world lacks a system of effective safeguards for managing the risks of biotechnology. "Scientists may do their best to follow rules for the responsible conduct of research," he said. "But efforts to harmonize these rules on a global level are outpaced by the galloping advance of science itself, and by changes in the way it is practiced." To address this policy challenge, Annan called for the creation of a "global forum" under U.N. auspices so that representatives from governments, industry, science, public health, law enforcement, and the public could discuss how to ensure biotechnology serves the common good.

Since Annan's retirement, however, the idea of a global forum has languished. It's time for his successor, U.N. Secretary-General Ban Ki-Moon, to take up the proposal and make it a reality. The reason: Preventing the misuse of biotechnology for the creation of weapons of almost unimaginable horror will require coordinated global action that only an international forum can muster. There is simply no way the United States can tackle this dangerous problem on its own.

## THE CHALLENGE OF "DUAL-USE" RESEARCH

So what are the security implications of biotechnology that prompted Annan's proposal? One concern is that many biotech facilities, equipment, and materials are inherently "dual-use," meaning that they can be applied either for legitimate civilian purposes or for the development and production of biological weapons. Moreover, whereas biotechnology was once the exclusive domain of advanced industrial countries such as the United States, Western Europe, and Japan, it is now a major focus of investment by developing countries such as China, Cuba, India, Indonesia, Malaysia, Singapore, South Korea, South Africa, and Taiwan.

There are many good reasons for the spread of biotechnology: it can enhance public health, improve agricultural yields, and foster economic development. Yet the proliferation of dual-use biotechnologies to unstable regions of the world, where war, trafficking, and terrorism are rife, is potentially a recipe for disaster. In addition to the risk that biotech facilities, equipment, and materials might be diverted to bioweapons production, state or non-state actors could conceivably exploit certain types of scientific information generated by biomedical research for hostile purposes.

Historically, scientists have viewed the discovery of new knowledge as an unalloyed good that contributes to human understanding of the natural world and leads to beneficial applications. But bioethicist Arthur Caplan of the University of Pennsylvania argues that some types of scientific information are dangerous in the wrong hands. "We have to get away from the ethos that knowledge is good, knowledge should be publicly available, that information will liberate us," he says. "Information will kill us in the techno-terrorist age."[2]

Given these concerns, a philosophical question facing the life-sciences community is whether certain areas of research constitute "forbidden knowledge" that should be banned or otherwise restricted on security grounds. Controversy over the risks of dual-use research first erupted in early 2001, when Australian scientists published a paper in the *Journal of Virology* reporting the finding that insertion of a single gene for an immune-system protein into the mousepox virus made this normally benign virus extremely lethal in mice, even those that had been vaccinated against it. Because bioweapons developers could possibly use the same manipulation to increase the lethality and vaccine resistance of related viruses that infect humans, such as monkeypox, critics argued that the information was dangerous and should not have been published.

To examine this emerging debate, the National Research Council (the policy analysis arm of the U.S. National Academies) convened an expert committee chaired by Gerald Fink, a biology professor at the Massachusetts Institute of Technology. In late 2003, the Fink Committee released its report, *Biotechnology in an Age of Terrorism*. It concluded that certain types of basic research in the life sciences, although conducted for legitimate purposes, could indeed generate findings that might be misused by others to threaten public health or national security.

The Fink Committee identified seven "experiments of concern" that would render a pathogen more deadly or transmissible, able to infect additional species, resistant to existing vaccines or therapeutic drugs, easier to convert into a weapon, or capable of evading diagnostic or detection techniques.[3] In response to one of the committee's recommendations, the Bush administration established the National Science Advisory Board for Biosecurity, which met for the first time in mid-2005.

The NSABB's mandate is to develop criteria for identifying dual-use research, draft guidelines for the review and oversight of risky experiments, and recommend possible restrictions on the publication of sensitive data. The board consists of up to 25 voting members from the U.S. scientific and national security communities, along with non-voting representatives from the 15 federal agencies that conduct or support research in the life sciences.

## EXPERIMENTS OF CONCERN

To give a recent example of dual-use research, in June 2007 researchers at Germany's Helmholtz Center for Infection Research reported in the journal *Cell* that they had altered the DNA of the *Listeria* bacterium, a human pathogen, to enable it to cause disease in mice, a species it does not naturally infect.[4] This finding opened the way to developing a mouse model of *Listeria* infection, a key step in developing new treatments for the disease.

Yet the experiment has troubling security implications because the technique used to modify the host range of the bacterium could potentially be applied in reverse, enabling an animal pathogen to infect humans. Despite this risk, the editors of *Cell* did not seek outside advice about whether to publish the study. Moreover, because the German researchers could have published their work in a European journal, this case suggests that U.S. controls on dual-use research will not be effective unless other countries sign on.

Another emerging area of biotechnology with security implications is synthetic biology, which involves the design and synthesis of long strands of DNA.[5] The DNA molecule encodes genetic information with an alphabet of four "letters," or nucleotide bases (A, T, G, and C), which can be strung together in any conceivable sequence. The advent of automated DNA synthesizers has spawned a new industry in which hundreds of companies around the world—including firms in China, India, and Iran—can synthesize DNA sequences to order. A researcher seeking a particular piece of DNA simply goes to the supplier's web site, enters the desired nucleotide sequence and a credit card number, and several days later a vial containing the synthetic DNA arrives in the mail.

A small fraction of DNA-synthesis companies, known as "gene foundries," are capable of making gene-length strands of DNA consisting of thousands of nucleotide base-pairs. These segments can then be assembled in the right order to form an entire genome—the full complement of genes coding for a microorganism. Since 2002, scientists have used this technique to reconstruct two human viruses in the laboratory: poliovirus (7,741 base-pairs) and the formerly extinct Spanish influenza virus (13,500 base-pairs), the latter of which killed tens of millions of people during the worldwide pandemic of 1918–19. Both synthetic viruses have been shown to be infectious and capable of causing illness in experimental animals. Given the rapid advances in automated DNA synthesis, it is only a matter of time before it becomes possible to synthesize larger viruses in the laboratory, such as Ebola virus (about 19,000 base-pairs) or even smallpox virus (185,000 base-pairs). This development would make it possible to circumvent the physical security measures that currently keep such deadly pathogens out of the wrong hands.

A more ambitious goal of synthetic biology is to create novel genetic circuits that would enable microorganisms to perform practical tasks, with applications in medicine, computation, environmental remediation, and energy production. Futuristic examples are giving bacteria the ability to sequester carbon dioxide or to manufacture hydrogen fuel. To facilitate the design and construction of genetic circuits, Prof. Drew Endy and his colleagues in MIT's Department of Biological Engineering have compiled a "tool kit" of pieces of DNA with well-characterized functions. The idea is to assemble these components into functional genetic circuits, much as electronic devices are built from transistors, resistors, and diodes.[6]

To date, synthetic biologists have demonstrated the basic concept by performing a series of ingenious parlor tricks. For example, they have designed genetic modules that cause bacteria to blink on and off like microscopic Christmas-tree lights, or to become light-sensitive so that a lawn of the bacteria behaves like a photographic plate.

Despite the potential benefits of synthetic biology, the field could provide individuals with malicious intent with new ways to cause harm. For example, it may become possible to engineer novel viral or bacterial genomes capable of expressing toxins or virulence factors for which no natural immune defenses exist, and against which existing therapeutic drugs are powerless.[7] In addition, as synthetic biology diffuses widely, a new breed of "biohackers" might emerge, intent on showing off their prowess by developing real viruses rather than digital ones.

The potential misuse of biotechnology for hostile purposes is not limited to the development of more deadly microbial and toxin agents. Following on the work of the Fink Committee, another National Research Council panel co-chaired by virologists Stanley Lemon and David Relman issued a report in early 2006 titled *Globalization, Biosecurity, and the Future of the Life Sciences*,[8] which concluded that several other areas of biotechnology and biomedical research also pose dual-use dilemmas.

One case in point: Advances in drug delivery systems, such as needle-free systems for administering insulin to diabetics in the form of an inhalable aerosol, have security implications because aerosolization is the optimal method for disseminating biowarfare agents over large areas.

## PROPOSED OVERSIGHT MECHANISMS

What can be done to manage the risks of dual-use research in the life sciences without causing significant harm to the scientific enterprise? The U.S. National Science Advisory Board for Biosecurity has defined "dual-use research of concern" as follows:

> *Research that, based on current understanding, can be reasonably anticipated to provide knowledge, products, or technologies that could be directly misapplied by others to pose a threat to public health and safety, agricultural crops and other plants, animals, the environment, or materiel.*[9]

This definition sets the threshold fairly high: The risk of misuse must arise directly from the research findings and have significant implications for public health, agriculture, or national security. For example, an experiment that creates a highly virulent organism, but one that cannot be readily transmitted to humans, would not be considered a major threat.

Any effective global system for regulating biotechnology will have to be based on common standards for laboratory security and research oversight, which countries would implement and enforce on a national basis.

The NSABB has developed draft guidelines for the oversight of federally funded research in the life sciences to minimize the risk of misuse for hostile purposes, but national biosecurity measures are not sufficient. Because biotechnology is a global activity, managing its downside risks will require adopting policies at the international level to ensure that only legitimate scientists have access to deadly pathogens and to oversee potentially dangerous research. At present, biosecurity rules vary widely from country to country, creating a regulatory patchwork with gaps and vulnerabilities that bioterrorists could exploit as targets of opportunity. Moreover, if other countries adopt weaker guidelines than those of the United States, then the anticipated security benefits of the U.S. regulations will not materialize, and American researchers and scientific journals will find themselves at a competitive disadvantage.

Any effective global system for regulating biotechnology will have to be based on common standards for laboratory security and research oversight, which countries would implement and enforce on a national basis.[10] In 2006, the World Health Organization took a useful first step in this direction by issuing a set of guidelines for securing dangerous pathogens in locked cabinets, vetting laboratory personnel to make sure they are bona fide scientists, and keeping accurate records, but only some researchers have adopted these rules.[11]

More action is clearly needed. To prevent the misuse of biotechnology, the Lemon-Relman report called for creating a "web of prevention" extending from the individual scientist to global level. Key elements of this web are the norm against biological warfare enshrined in the Biological and Toxin Weapons Convention of 1972, transnational networks of scientists and other stakeholders, export-control regimes, professional codes of conduct, and educational and awareness efforts.

It is unclear, however, what institutional mechanism could serve to coordinate biosecurity measures at the global level. Although the Vienna-based International Atomic Energy Agency inspects civilian nuclear plants around the world to ensure that fissile materials are not diverted for nuclear weapons, it is a poor fit with biotechnology. The nuclear industry consists of a limited number of facilities and stocks of radioactive materials that are amenable to precise accounting, yet the biotechnology industry is extremely diffuse and involves the use of self-replicating organisms that cannot be tracked in a quantitative manner.

Harvard University biochemist Matthew Meselson warns that 21st century biotechnology will make it possible not only to devise additional ways to destroy life, but also to manipulate the processes of cognition, development, reproduction, and inheritance, creating "unprecedented opportunities for violence, coercion, repression, or subjugation." He says that "movement towards such a world would distort the accelerating revolution in biotechnology in ways that would vitiate its vast potential for beneficial application and could have inimical consequences for the course of civilization."[12]

Given these very real dangers and the complex challenges of developing an international mechanism to manage the risks of biotechnology, there is an urgent need to establish Kofi Annan's proposed "global forum." U.N. Secretary-General Ban should not miss the opportunity to address one of the major security challenges of our time. sp

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ENGINEERING

AP PHOTO/ST. PAUL PIONEER PRESS, SCOTT TAKUSHI

# Catching Crumbling Infrastructure

## Sensor Technology Provides New Opportunity

By Reece Rushing

**ALMOST A YEAR AGO,** an eight-lane interstate bridge in Minneapolis collapsed during evening rush hour, killing 13 people and injuring 144. This collapse, and the failure to anticipate it, called into question the adequacy of current bridge inspection methods. Why were problems with the bridge not identified? And if problems were missed in Minneapolis, could they be missed elsewhere? Could this happen again?

There is good reason to worry. Before it collapsed, the Minneapolis bridge was one of more than 70,000 bridges nationwide declared by the Department of Transportation to be structurally deficient. One in three urban bridges fall into this category.

Such bridges may be safe for travel so long as they are carefully monitored. Recent advancements in sensor technology provide the opportunity to collect detailed, real-time data on bridge performance. But this technology is being used on less than a handful of bridges nationwide. Current inspection methods, unfortunately, cannot be relied on to catch a bridge on the brink of collapse.

"We do not know which bridges should be taken out of the system, and which should be maintained," said A. Emin Aktan, a professor of civil engineering at Drexel University and director of the Intelligent Infrastructure and Transportation Safety Institute.

Every two years, each government-owned bridge is required to receive a "routine" inspection, in which technicians or engineers observe the bridge and take measurements of its physical condition. Underwater structures, meanwhile, must be inspected by divers every five years. There are guidelines but no requirements for "in-depth" inspections, which can include things like probing of the bridge, laboratory analysis of bridge material, and testing of surrounding environmental and water conditions.

This heavy reliance on visual inspection is inadequate for three major reasons. First, inspections are susceptible to human error. Indeed, a 2001 study by the Federal Highway Administration found that inspectors regularly missed problems and inconsistently rated bridge conditions. Second, there are long intervals between required inspections, during which time serious problems may emerge. And third, inspections may be superficial and might not produce the detail necessary to spot deficiencies.

This is not to say that visual inspection is unimportant—visual inspection is crucial to assess bridge conditions, in particular cracks and corrosion. But more is needed to assure the safety of the nation's bridges.

That's where sensor technology comes in. Instead of relying on sporadic and error-prone observations, matchbox-sized wireless sensors can be attached or embedded on bridges to take precise, continuous measurements of virtually anything relevant to a bridge's condition, including strain, tilt, vibrations, temperature, and seismic activity. This sort of data is particularly important as the nation's bridge population ages—the mean bridge age is now 40 years old—and traffic and truck loads continue to increase, causing more rapid deterioration.

The Minneapolis collapse created a political opportunity to modernize bridge monitoring. In its aftermath, Secretary of Transportation Mary E. Peters initiated an ongoing review of the agency's bridge inspection program to, in her words, "make sure that everything is being done to keep this kind of tragedy from occurring again."

Congress, meanwhile, is also engaged in finding solutions. Rep. James Oberstar (D-MN), chairman of the House Transportation Committee, has introduced legislation to significantly improve bridge inspection requirements as part of "a data-driven performance-based approach to systematically address structurally deficient bridges on our nation's core highway network."

Sensor technology can help meet the goals expressed by Peters and Oberstar. What's needed now is a plan to move forward.

## FIRST STEPS FOR SENSOR TECHNOLOGY

Recently, the Federal Highway Administration awarded funding to the Connecticut Department of Transportation and the University of Connecticut to deploy and study different types of sensor systems for long-term bridge monitoring.

"The goal is to generate information between inspections, so that if there's a major change, we can take action to prevent something catastrophic from happening," said project leader John DeWolf, a professor of civil engineering who became involved in bridge monitoring following the 1983 collapse of the Mianus River Bridge on Interstate 95 in Greenwich, Connecticut.

Over the last several years, six bridges in Connecticut have been outfitted with unique sensor systems. Five of these are wired systems, in which cables connect the sensors to a computer. The sixth relies on solar-powered wireless sensors. This wireless system is particularly exciting because it holds great promise to be more widely replicated.

It can take a great deal of labor and expense to run cables over a bridge—especially one that is large and difficult to access. For a wireless system, however, cables are not an issue. Sensors merely need to be placed in desired locations on the bridge. Installation typically takes no more than a few hours, at a cost less than half that of a wired system.

Because of these advantages, DeWolf decided to go wireless for Connecticut's longest bridge, the Goldstar Bridge, which crosses the Thames River on Interstate 95 in New London. Like all new technologies, wireless sensors are expected to get much cheaper over time. But even now they are affordable. Installation of 12 sensors at the Goldstar cost about $30,000.

Over the long run, sensors may even pay for themselves by more precisely identifying when and where repairs are needed. Ten wireless sensors were recently used to test stress levels from passenger trains on the Ben Franklin Bridge, which crosses the Delaware River from Philadelphia to Camden, New Jersey. The state believed the bridge was in need of major repairs based on advice it received from an engineering consultant. But data gathered by the sensors showed the bridge was in fact secure, saving tens of thousands of dollars in unnecessary repairs.

Sensors can also reveal problems as they emerge—before there is visual evidence such as cracking. This allows remedial action to be taken in time to head off serious structural damage, which can be very expensive to repair. "If you get to it quickly and fix it, it's not going to be a major problem," said Mike Robinson, vice president for sales and marketing at MicroStrain Inc., which developed the sensors for the Ben Franklin Bridge. "You can reduce the overall life-cycle cost of the bridge."

DeWolf approached MicroStrain to develop the solar-powered sensors specifically for the Goldstar. The sensors used on the Ben Franklin Bridge were powered by batteries—fine for short-term testing, but not long-term monitoring. Batteries eventually run out of power and need to be changed or recharged, which is a difficult task on a bridge like the Goldstar, where sensors are in hard-to-reach locations.

The solar-powered system relies on photovoltaic panels to harvest energy from the sun. These panels are connected to the sensors to supply power for daytime monitoring and recharge batteries for overnight observation. This system is expected to generate power for years with little or no maintenance. MicroStrain is also developing other solutions for long-term power, including mini wind turbines and super efficient battery-powered sensors, according to Robinson.

MicroStrain first installed its solar-powered system on the Corinth Canal Bridge in Greece to monitor seismic activity. There, the sun is strong enough for continuous monitoring, which is crucial given the unpredictability of seismic activity. At the Goldstar, where the sun is not as bright, data are gathered for five to 10 minutes every hour to conserve energy. For what's being measured, strain and vibrations, this is considered plenty sufficient.

The data collected are temporarily stored on the sensors and then downloaded daily to an onsite laptop computer. From there, the data can be remotely accessed through a DSL connection. Of course, it is not possible to manually analyze the voluminous amounts of data generated. Instead, automated systems are programmed to comb through and pick out relevant information for DeWolf and his team to review.

Ultimately, this information can help confirm whether the bridge is safe. Vibrations, for example, can be monitored to ensure that they do not exceed potentially dangerous thresholds. For the vast majority of the nation's bridges, this sort of information is not available. Indeed, Connecticut is now the only state using sensors for long-term monitoring of multiple bridges. Other states rely on the same visual inspection methods that failed in Minneapolis.

"Let's not debate that visual inspection has proven insufficient," Aktan said. "Instead, we should focus on strengthening bridge monitoring, so that one day there will be little worry about another bridge collapsing." Wider use of wireless sensor technology is an important part of the solution.

## BUILDING A NATIONWIDE SENSOR SYSTEM

In the aftermath of Minneapolis, public attention is now appropriately focused on detecting an imminent collapse. Thousands of the nation's bridges are badly in need of repair. The possibility that one might collapse is very real.

Installing sensors on all of the nation's 70,000 structurally deficient bridges, however, is not practical or even desirable. Within the "structurally deficient" category, there can be vast differences among bridges. Some bridges may be quite safe, in need of relatively minor repairs, while others may have major problems that should be addressed immediately.

The Federal Highway Administration, unfortunately, does not systematically identify priorities among these bridges. Nor are bridges of greatest concern necessarily given more attention. Rather, each bridge is subject to the same biannual requirement for visual inspection regardless of physical condition.

It is thus paramount that more detailed categories be developed that group bridges by degree of concern. High priority bridges, of course, should be repaired as quickly as possible. But repairs may take time to complete, or funding may not be immediately forthcoming. In the meantime, sensors could be deployed to provide more careful monitoring and help further refine priorities for repairs.

Sensors, however, should not only be installed on the very worst bridges. Ideally, they should be used to assist routine maintenance, so that bridges never get to the point of imminent collapse. This requires a system to smartly and economically deploy sensors to monitor the nation's entire bridge population.

The first step in this process is to classify bridges according to type. A suspension bridge like the Brooklyn Bridge obviously has different characteristics than a truss bridge like the Goldstar and the I-35 bridge that collapsed in Minneapolis. But even bridges of the same general type can have critical differences. Truss bridges, for example, employ a variety of bracing designs, may or may not use pins to connect joints, and may carry traffic on the top, middle, or bottom of the structure.

Bridges will deteriorate in different ways and at different rates depending on such variables. Currently, however, the nation's bridges are not carefully categorized by similar design features. This information is needed to determine which bridges to outfit with sensors.

Because similar bridges can be expected to perform alike, it is necessary to install sensors only on a sample from each category. Again, this sort of sampling is not part of the current monitoring system—each bridge is subject to the same biannual inspection. "Looking at each bridge as an individual is ridiculous," Aktan said. "There are tremendous similarities between certain types of bridges, but we don't leverage knowledge about those similarities."

The Federal Highway Administration recently launched an initiative—the Long-Term Bridge Performance Program—that begins to move in this direction. The goal of the program is to generate "high-quality, quantitative performance data" based on a representative sample of the nation's bridges, likely numbering 500 to 1,000 bridges representing the majority of structure types. This includes data on deterioration and its causes—traffic load, corrosion, fatigue, and weather, among others—as well as the effectiveness of maintenance strategies.

As part of its data-gathering efforts, FHWA intends to subject the bridges in its sample to detailed periodic evaluations, over at least a 20-year period, using sensor technology and other state-of-the-art monitoring tools. In addition, a subset of bridges in the sample will be instrumented to permit continuous monitoring, while decommissioned bridges will undergo forensic autopsies.

Congress created this program under legislation enacted in August 2005, with funding authorized through FY 2009. FHWA requested $20 million a year, but will have to operate with only about $5.5 million a year over the first four years. Thus, decisions must be made over which parts of the program to launch immediately and which to postpone pending higher levels of funding.

The initiative will be especially valuable in determining what data to collect and what the data means. In particular, it is not always clear what and where to measure. If sensors measure the wrong things or are placed in the wrong spot, they may miss critical deficiencies. FHWA's research will begin to identify key factors and pressure points in the deterioration of different types of bridges. "A doctor knows where to take a patient's pulse," Aktan said. "We need to know where to take the bridge's pulse."

A critical part of this process is knowing how to interpret the pulse, so that sick bridges are diagnosed and treated. The vast majority of bridges lack baseline performance data—that is, data collected at the time they were built—from which to judge deterioration over time. Without this information, there is uncertainty about a bridge's optimal performance and exactly what constitutes poor performance.

FHWA intends to address this problem by comparing newer and older bridges of similar type to identify and predict life-cycle changes. This should bring into sharper focus the large amounts of data generated by sensors. "The problem we have now is making sense of this data," said an FHWA engineer involved in the Long-Term Bridge Performance program. "That's what we are trying to address. Determining the sample of bridges is the most critical step." FHWA has already developed methodology to identify bridges for the sample. A final selection of bridges will be made in collaboration with the Center for Advanced Infrastructure and Transportation at Rutgers University, which was contracted in April to oversee the program's day-to-day operations.

FHWA's research deserves the full support of Congress and the administration. The amount currently appropriated is barely enough to get off the ground. One enduring problem, unfortunately, is the tendency of Congress to fund transportation research through earmarks to specific universities or private contractors. These earmarks sometimes go to worthy projects, but frequently they are awarded according to political considerations rather than merit.

Moreover, because funding is disjointed and somewhat arbitrary, transportation research is not well integrated and coordinated. The Long-Term Bridge Performance Program can help add cohesion by drawing together information generated by disparate research efforts, including other FHWA-funded initiatives such as the sensor project in Connecticut. "We will try to piggyback on other research projects and make them fit into this national approach," the FHWA engineer said.

## CONFRONTING THE INFRASTRUCTURE CRISIS

For years, the president and Congress have repeatedly deferred needed maintenance of bridges in favor of other budgetary priorities. This shortsightedness will cost the nation far more in the end, as the scale and severity of needed repairs balloon and become impossible to ignore. For Minneapolis, the Department of Transportation released $55 million in emergency funds and Congress authorized $250 million for rebuilding.

Other critical infrastructure—including roads, dams, and levees—are similarly deteriorating and could also benefit from enhanced monitoring through sensors. Substandard road conditions contribute to 30 percent of all fatal highway accidents, according to the FHWA. More than 3,500 dams are unsafe or deficient, many of which may not hold during significant flooding or an earthquake, according to state inspectors. And nearly 150 of the nation's levees pose a high risk of failing during major flooding, according to the U.S. Army Corps of Engineers. The American Society of Civil Engineers, which gathered these statistics, terms the current situation an "infrastructure crisis."

The Minneapolis bridge collapse provided dramatic evidence of this crisis. But it was by no means an isolated event. In March 2006, for example, an earthen dam in Kauai, Hawaii gave way and let loose nearly 300 million gallons of water, killing seven people. In late 2005, a 120-ton concrete beam fell from a bridge in Pennsylvania onto Interstate 70. And of course, the levees in New Orleans were not only breached during Hurricane Katrina, but structurally failed.

It is crucial that investments are made to upgrade the nation's crumbling infrastructure. In the meantime, however, more failures should be expected. The question now is whether we will be able to anticipate these failures in time to head off disaster. Sensor technology, if effectively implemented, would give reason for hope. sp

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FINANCING SCIENCE

# BRIDGING *the* VALLEY *of* DEATH

## Cocaine Vaccine Efforts a New Financing Model for Drug Development

By Mark Meier

The "war on drugs," that well-worn phrase trotted out by presidents past and present,

is today almost devoid of real strategic meaning, especially when it comes to the cocaine epidemic that has swept our nation. Supply-side theorists advocate destroying coca fields and tightening America's borders. Demand-side advocates insist on more Drug Abuse Resistance Education in schools and stiff sentences for cocaine—the better to lower demand on the streets. Neither seems to be working very well.

Now, an experimental vaccine to treat cocaine addiction may well upend the stale strategies that underpin the "war on drugs." If the vaccine proves effective in clinical trials, then "Just Say No" may take on an entirely new meaning: your body will agree even if your mind wants to say yes.

If the vaccine does prove to be efficacious, it is not just the science that should be applauded. So, too, should the public- and private-sector financing model that would have funded the vaccine all the way to the marketplace—something that hardly ever happens with vaccines in the world of drug development. The applause, however, for bridging this financial "valley of death" might just stop there. The reason: profitability is not at all assured even if the last clinical trials prove successful.

Public health officials must then answer the question of "who gets vaccinated," which in turn will determine just how much money the private investors behind the cocaine vaccine will reap in profits from the more than decade-long effort to bring it to market. This cocaine vaccine, then, boasts a number of potential lessons for scientific researchers, public and private investors in vaccine development, and public health professionals and policymakers.

## A NOVEL VACCINE PATHWAY

Researchers at the Baylor College of Medicine in Houston requested permission in December 2007 from the Food and Drug Administration to begin Phase III clinical trials for a vaccine called TA-CD. These late-stage clinical trials will test the efficacy of TA-CD's ability to blunt or even to prevent cocaine's effects on users among a group of several hundred humans, which if successful would move the drug very close to commercialization.

Reaching Phase III trials is a monumental achievement, as very few drugs make it that far in the research-and-development and regulatory approval phases of development. And for TA-CD, it's been a long time coming. The TA-CD vaccine first made headlines in 1996, when Barbara Fox and collaborators published in *Nature Medicine* that rats could be inoculated against cocaine's euphoria.[1] The same approach then proved feasible in early stage clinical trials with about 20 humans. By attaching the cocaine molecule to an inactive cholera protein, the TA-CD vaccine stimulates the subject's immune system to produce antibodies that bind to cocaine and prevent it from passing from the blood into the brain, which means vaccinated users no longer experience the same high from cocaine, and hence, demand it less.

The initial vaccination is usually administered in several shots over weeks or months, which trains the body to associate cocaine with cholera. Results from 2005 suggest a booster shot is necessary every four months to maintain the vaccine's efficacy, which has been enough time for some people in trials to cut their cocaine use significantly.[2]

TA-CD is not the first vaccine to combat drugs. In 1974, for example, Dr. Charles Schuster (then at the University of Chicago) developed a vaccine that prevented monkeys from getting high on heroin, but he and other researchers opted not to pursue its application to humans because users could easily switch to other opiates. One of those other opiates, methadone, is commonly used to wean heroin addicts from their habit. It is not yet clear if TA-CD will suffer the same drawbacks, or if users could increase their dosage dramatically—and dangerously—to defeat the vaccination. The initial trials, however, have found no users tried either approach to circumvent TA-CD.

The idea of fighting addictions—including cocaine—with vaccines, however, did not end with methadone. The National Institute of Health's National Institute on Drug Abuse has emphasized that approach since it founded the Medication Development Program in 1990. The federal government today currently lists around 200 NIDA-funded clinical trials that use drugs to change how cocaine and your brain interact.[3]

Most of those drugs approved for actual use in the marketplace were first approved for other uses but also showed some ability to dampen cocaine's impact by affecting brain function. Modafinil, for example, is sold as Provigil to treat narcolepsy. Disulfiram (better known as Antabuse) makes people crave cocaine less and feel much more paranoid when they take it, similar to how Antabuse makes people ill when they imbibe alcohol. A third drug, baclofen, started as a muscle relaxant.

Yet another drug, buprenorphine—which can be injected during surgery as a painkiller—also counters cocaine when taken orally, though it has been studied more as a tool to fight heroin addiction. Buprenorphine will soon enter a large trial on prison inmates to see if it reduces how much they use heroin and, secondarily, cocaine, after they return to regular life in Baltimore.

Among all these drugs, however, only the TA-CD vaccine stops cocaine from interacting with the brain at all. It arrests the narcotic in the bloodstream, where it can be metabolized into less harmful pieces. That is its physiological revolution.

## A NOVEL FINANCIAL PATHWAY

The financial revolution is that a vaccine that does not target an especially wealthy or wide audience may still make money for its private investors. TA-CD development built a novel bridge over the so called "valley of death" funding gap between basic biomedical research and development and—perhaps—eventual drug commercialization.

Public money supported the initial research on demand-side efforts to counter cocaine addiction, as is almost always the case in experimental efforts to develop drugs for markets limited in size or lucre. But public money then also helped finance the development of the vaccine at later stages of its development alongside private, venture capital investors as the drug passed one test after another.

The leading researcher on the TA-CD vaccine trials, Thomas Kosten, today has $3 million in grants from NIDA to study cocaine treatments, and has spent about five times that much in previous grants since the late 1990s. Kosten ran his earlier trials at a Veteran's Administration hospital in New Haven, Connecticut. Now that Kosten has moved from Yale to Baylor, he runs the trials from the Michael DeBakey VA Hospital in Houston.[4]

Celtic Pharma, a Bermuda-based firm that invests in drug development start-up companies around the world, bought Xenova, a British company working on the TA-CD vaccine in August 2005. Kosten received money from Xenova for consulting but has cooperated with many companies as the drug changed hands several times during clinical trials over the previous decade. When Celtic Pharma bought Xenova, the acquired company was concurrently developing a vaccine approach to nicotine with similar success under the name TA-NIC. That drug will likely begin Phase III trials soon, and competitors are working on their own versions.

Previously, in 2001, Xenova had acquired both vaccines from another British company, Cantab Pharmaceuticals. Cantab, in turn, got the drugs when it bought the vaccine program of ImmuLogic Pharmaceutical Corp., operating in Massachusetts with nominal headquarters in Delaware. ImmuLogic also worked on allergy medications and held the patent for the technique common to TA-CD (known as IPC-1010 at the time), and TA-NIC: binding addictive substances to immunogenic compounds, an approach known as hapten-carrier conjugates.

Tens of millions of dollars changed hands in these three deals.[5] But it all started when NIDA awarded ImmuLogic a Small Business Innovation Research grant of $700,000 in 1996 to develop a vaccine for humans.[6] Now, more than a decade later, public and private financing has carried the vaccine to Phase III clinical trials, which are about to commence and are expected to last one to two years.

Celtic Pharma (according to its website)[7] sees these types of drugs as potential blockbuster investments that could "build real value by driving them through the final stages of the approval process" with the intention to "achieve extraordinary returns for its investors by monetizing these important and innovative drugs." A mix of biotech and hedge fund veterans, Celtic Pharma stands at the end of a long chain of investors, though without NIDA funds driving the research and federal hospitals providing some of the infrastructure through the first phases of clinical trials, the TA-CD vaccine might never have emerged from the Petri dish.

> Federal dollars spent over the entire course of the development process, with additional private sector funding, may well produce a marketable vaccine for the public good.

The upshot: federal dollars spent over the entire course of the development process, in tandem with lots of additional private sector funding, led to what may well be a marketable vaccine that could well produce a public good—fewer people in the thrall of cocaine addiction.

## THE PUBLIC HEALTH PATHWAY

The story of TA-CD doesn't end there, however, either scientifically or financially. If the clinical trials are as successful as the developers of the vaccine hope they will be, then policymakers in the United States and abroad will have plenty to consider. Indeed, this potential physiological revolution has already prompted much discussion about the public health implications of vaccinating current or possibly future users.

With TA-CD facing only a few—though still significant—hurdles on its way to the marketplace, questions have been arising about this novel way to tame a social problem with the standard tools of public health. Cocaine addicts would probably benefit from the vaccine, and hypothetically the U.S. government and public health officials in other countries might be able to contain the spread of cocaine contagion by inoculating parts of the general population.

That hypothetical, however, in turn has already raised questions about who might be required or encouraged to try the vaccine and under what circumstances. Should TA-CD be considered in the standard childhood battery of measles, mumps, and rubella shots? Should it be administered to all adolescents? Or should it be limited to more definable "at risk" groups, such as those arrested for drug use who are about to be released from prison?

Less sanguine comparisons have been made to the contraceptive Norplant,[8] which U.S. courts in the early 1990s offered women in the criminal justice system as an alternative to tougher prison sentences. Critics said Norplant was a dubious way of biologically-based social control to shrink the so-called underclass. Norplant was later yanked from U.S. markets because the drug displayed some significant side effects.

The National Academy of Sciences is already considering similar questions, having published in 2004 a book on immunotherapies for addiction entitled *New Treatments for Addiction: Behavioral, Ethical, Legal, and Social Questions*. That study essentially recommended thinking long and hard about using immunotherapeutic drugs to treat drugs of abuse, including how to make vaccines more permanent, how to protect people from coerced vaccination, and how to anticipate changes in the drug market or users' behavior in response to the vaccine.[9]

How public health officials decide to distribute the TA-CD vaccine—providing it clears Phase III clinical trials and is then approved for sale to the general public by the U.S. Food and Drug Administration—will be enormously consequential financially for TA-CD's investors and society at large. In the end, those decisions may well determine whether this novel approach to researching and financing this public good succeeds for all involved. And if it works well for all, then it may well spark other private-public partnerships in search of other novel techno-chemical methods to tackle the scourge of addictive drugs in our society today. sp

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**NOTES**

1 Barbara Fox, et al. "Efficacy of a therapeutic cocaine vaccine in rodent models," *Nature Medicine* 2 (1996): 1129–32. Available at http://www.nature.com/nm/journal/v2/n10/abs/nm1096-1129.html.

2 Thomas Kosten and S. Michael Owens, "Immunotherapy for the treatment of drug abuse," *Pharmacology and Therapeutics* 108.1 (2005): 76–85. Available at http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TBG-4GMGW53-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=659bc0b778788646614ccc7e9788a09b.

3 The NIH operates the website to track clinical trials in the United States and 150 other countries. See http://clinicaltrials.gov/.

4 Dr. Kosten's curriculum vitae, including grant information, can be found at http://www.bcm.edu/psychiatry/?PMID=7342.

5 Information on the various transactions can be found at http://sec.edgar-online.com/2001/03/20/0000950135-01-000851/Section18.asp; http://sec.edgar-online.com/1997/03/31/00/0000950135-97-001528/Section2.asp; and http://www.secinfo.com/d14SA9.zAc.d.htm.

6 The NIH lists grant funding at http://grants.nih.gov/grants/funding/sbirsttr96.txt and http://grants.nih.gov/grants/funding/sbirsttr97.txt.

7 www.celticpharma.com.

8 See, for two examples, Dru Stevenson's article "Libertarian Paternalism" available at http://www.rutgerspolicyjournal.org/journal/vol3issue1currentIssues/Stevenson_Paternalism.pdf or the Center for Cognitive Liberty and Ethics' report "Threats to Cognitive Liberty: Pharmacotherapy and the Future of the Drug War" available at http://www.drugpolicy.org/docUploads/Pharmacotherapy2004.pdf.

9 The text is available from http://books.nap.edu/openbook.php?record_id=10876&page=R1.

SCIENCE PUBLISHING

US NATIONAL LIBRARY OF MEDICINE

# Public Science

## NIH's New Open Access Policy Can Benefit Everyone

By Gavin Baker

**TUCKED AWAY IN THIS YEAR'S** federal budget is a provision that benefits the scientific community without spending a dime: a mandate for public access to the results of research by National Institutes of Health grantees.

The policy is the first open access mandate adopted by the U.S. government, and puts teeth into the voluntary policy in place at the agency since 2005. The NIH, which supported the provision, moved quickly to implement the law, announcing its new policy on Jan. 11. The measure follows similar policies instituted by funding agencies abroad, foundations, and universities.

Under the new policy, grantees—who will receive $29 billion in taxpayer funding in fiscal year 2008, a figure greater than the GDP of 100 countries—will deposit a copy of their research articles accepted for publication into the National Library of Medicine's PubMed Central database. PubMed Central will then provide free online access to the article—to the worldwide research community as well as citizens and taxpayers. Public access can be delayed up to one year at the researcher's request, for example, if the publishing journal asks for the delay. Previously, grantee research was only available from the publisher by subscription—and scientific journal subscriptions can cost thousands of dollars annually.

The new policy is not only notable for its novelty and the whopping amount of research it will make available, but also for the political clash it sparked. In 2007, open access advocates ramped up their efforts, led by the Alliance for Taxpayer Access—a letterhead coalition driven by the Scholarly Publishing and Academic Resources Coalition, a consortium of academic libraries. (Full disclosure:

the author is a consultant and former intern for SPARC.) In addition to rallying grassroots support, advocates circulated a letter of support signed by 26 Nobel Laureates, including former NIH director Harold Varmus.

Opponents, led by members of the Association of American Publishers, launched a coalition—dubbed PRISM, the Partnership for Research Integrity in Science and Medicine—to cast doubts on the provision's impact on the peer review process and publisher copyrights, even equating public access with government censorship. PRISM in turn drew ridicule from science bloggers, who criticized the group's statements as Orwellian and the group as astroturf, as PRISM declined to list its own membership. Even some AAP members distanced themselves from the effort. PRISM was seen as the offspring of Eric Dezenhall, known as "the pit bull of PR," who had been hired by the AAP to develop a PR strategy to combat open access.

In the end, the open access provision was signed into law late last year—the biggest legislative victory to date for the American open access movement and, given the size and impact of NIH funding, for advocates worldwide. The adoption of the policy will introduce more authors to self-archiving—posting one's own research results online for free access—then any single event to date. NIH funding results in an estimated 80,000 published articles annually, each of which may have several authors.

With any luck, the experience will encourage researchers to internalize the benefits of open access—and to share their experience with the students they teach and mentor. Journals likely will not suffer many, if any, cancellations. High rates of self-archiving in physics have not resulted in any attributable cancellations of journals in that field—though they may feel more pressure to provide value and limit price inflation. From 1986 to 2002 journal costs rose 227 percent, more than triple the rate of inflation in the same period as measured by the Consumer Price Index. But science and consumers will benefit immeasurably.

Researchers will gain more complete access to the scientific record; even the wealthiest research institution cannot afford to subscribe to every journal in publication. Free online access also lays the foundation to remove unnecessary permission barriers, using approaches such as the Creative Commons licenses, and to facilitate machine-assisted research via Semantic Web technologies. Taxpayers will benefit from free access to high-quality scientific information; for those without an annual subscription, content is often sold for $30 apiece.

In the case of NIH research, that could mean the best source of information about potential treatments for a spouse, parent, or child who suffers from a disease. Indeed, patient advocacy groups are well-represented and active members of the pro-open access Alliance for Taxpayer Access, including the 600 organizations of the Genetic Alliance.

Moreover, the impact of the NIH policy will be felt outside of biomedical research. If NIH grantees take a shine to open access, then it will become even more difficult for publishers and nay-sayers to disparage open access. As the PRISM coalition found out, scientists don't take kindly to being told their research is junk just because it is shared for free.

Other research funding agencies will find more courage to pursue open access policies of their own, perhaps paving the way for a government-wide mandate akin to the Federal Research Public Access Act floated by Sens. John Cornyn and Joe Lieberman. Some may even push for stronger mandates than the NIH policy—such as the European Research Council policy released on Jan. 10, which halves the NIH's maximum allowable delay from 12 months to 6.

Open access is a positive development for several goals of science policy: to accelerate research, control costs in higher education, and share information more effectively. The NIH public access policy will move forward on all three fronts and pave the way for progress to come. sp

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LIFE SCIENCES


# Abortion and the Slippery Slope

## The POPLINE Controversy, Language, and Scientific Integrity

By Pablo Rodriguez, Wayne C. Shields, and Jennifer Aulwes

**CALL IT CENSORED,** call it buried, call it lost—the search term "abortion" was all of the above for approximately a month on POPLINE—a publicly-funded database that its administrators describe as "Your connection to the world's reproductive health literature."

In early April, researchers at the University of California, San Francisco, uncovered this ironic situation while trying to "connect" to "reproductive health literature." Health care providers, researchers, and advocates around the country were alarmed to learn that POPLINE (POPulation information onLINE), had rendered the search term "abortion" a stopword—which directs the database to ignore the term when used in a search. UCSF librarians discovered this deliberate restriction when they were unable to find a single document containing the word "abortion" in POPLINE's database, and contacted the administrators at the Johns Hopkins Bloomberg School of Public Health to ask them why.

Simply put, the UCSF librarians were told that "abortion" was eliminated as a search term by the POPLINE administrators so that the latter could examine the database for information "that might not have been consistent" with guidelines from a government agency that funds the project. And our UCSF colleagues were then given some mystifying, convoluted search term suggestions for finding medical literature on the subject, including "fertility control, post-conception" and "pregnancy, unwanted."

News of the self-censorship quickly spread like a virus. Countless members of the medical, scientific, and advocacy communities responded and within two days, Hopkins Dean Michael J. Klag issued a statement unequivocally denouncing the administrators' decision to censor the word abortion and promising to get to the bottom of it. Four days later, he issued a follow up statement citing his opposition to the decision and his speedy response, while blaming "an overreaction on the part of POPLINE staff" to a search by USAID [United States Agency for International Development] officials who "found two items in the POPLINE database that advocated for abortion."

So let's pause for a moment and review what happened: a vigilant literature search on the word "abortion" by unidentified Federal employees at USAID resulted in finding two abortion articles in the POPLINE database that they deemed to feature inappropriate advocacy. Once notified by the Feds, Hopkins administrators immediately made abortion a stopword—an additional step not requested by USAID, but implemented to allow administrators to search for other material that might have been inconsistent with the agency's guidelines—effectively ending access to abortion research to health professionals and the public on their 30-year-old database.

While giving credit to Dean Klag for his quick response to an untenable situation, there are two important questions that remain: Why are Federal employees at USAID so attentively monitoring scientific research articles on the POPLINE database for the word "abortion"? And why are Hopkins administrators so afraid of them? The Dean states that USAID is prohibited by law from funding any abortion activities or supplies. This is all the more reason for concern by researchers, civil libertarians, health care providers, and patients who deserve the best possible care. But the incident simply points to a larger problem: Federal policy regarding comprehensive reproductive health care is inadequate.

## THE REAL IMPACT OF LIMITING ACCESS TO INFORMATION

The medical and scientific needs of the reproductive health professional community were impeded by POPLINE's decision to remove abortion as a search term on its publicly funded database. If this action had gone unchecked, the decision would have limited the medical and scientific community's ability to access information on a range of patient care scenarios, including women experiencing both wanted and unintended pregnancies.

A clinician seeking information while providing abortion care services would have been unsuccessful in accessing key medical and scientific literature on the topic—potentially endangering the patient. Women with wanted pregnancies and their health care providers looking for information on spontaneous abortion (miscarriage), inevitable abortion, incomplete abortions, missed abortions, and related medical information would have also been denied this key data.

Unsafe abortion practices claim thousands of lives worldwide every year and any public health student, policy maker, or provider seeking vital information on the topic of unsafe abortion would have also come up empty-handed.

## IDEOLOGY TRUMPING SCIENCE IS ABOUT MORE THAN JUST ABORTION

The specter of ideology trumping science goes way beyond POPLINE and abortion. There is more visible political opposition to important health classifications like family planning, sexuality, and reproductive health than we have seen in years. Political posturing can get in the way of science, public health, and patient care—even POPLINE's reputation is potentially at risk.

Over the last seven years, we have witnessed an intentional blurring of the lines between opposition to abortion and a more general objection to contraception. For example, many of President Bush's anti-choice family planning political appointees have been openly anti-contraception as well. Bush's 2002 appointment to a key FDA panel, Dr. Joseph B. Stanford, complained about contraceptive use even among married couples. And more recently Bush appointed Susan Orr as the acting deputy assistant secretary for population affairs to oversee family planning funding for clinics serving poor women, even though she previously worked to limit access to contraception as the senior director for marriage and family care at the Family Research Council, an organization well-known for its anti-contraception stance. She has since resigned.

And now the term "reproductive health" is being targeted. At the United Nations, there are unbelievably rancorous debates about whether or not to include the terms "sexuality" and "reproductive health" in treaties because many politicians view them as faux terms for abortion.

It may have been that POPLINE staff made the decision based on fear of losing their USAID funding. USAID does have a history of basing reproductive care funding decisions at least partly on ideology and politics. For example, they have withheld funding from developing countries if potential grantees provide abortion services or give abortion referrals to women.

It's also possible the suggestion came from above. With the Bush administration's history of attempting to (and often succeeding in) restricting access to abortion services and information at every possible turn, it's not so unlikely they'd attempt to scrap the word altogether.

The bottom line is that even self-censorship of a specific term like "abortion" in a scientific setting—especially as a result of Federal government monitoring—sets a dangerous precedent. We must follow the example of our UCSF colleagues and make preserving access to reproductive health science a part of our own work plans. It's scary enough to consider the possibility that ideological searches are being performed by anonymous government employees who troll our scientific databases for the word "abortion." "Contraception," "sexuality," and "reproductive health" are the next stopwords, unless we remain vigilant and protest loudly. sp

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HEALTH IT

ISTOCKPHOTO

# Learning From Mom

## Promise of Electronic Medical Records Is in the Sharing

By Alan Muney

**TWO DECADES OF PEDIATRIC PRACTICE** taught me that the most reliable and effective repository for medical information is a mother's purse. Through changes in employment, in hometowns, and in the purses themselves, the immunization records of their kids always made the move along the journey from infancy through college.

Every mother keeping track of those immunization cards understood the importance of having them available for the next doctor or emergency room. The record's availability prevented her child from incurring unnecessary pain and possible vaccine reactions. In my pediatric practice, mothers of new patients helped my practice countless times, showing us the vaccines children had or were missing. Often, mothers carried multiple vaccine records from different physicians because each had given her an individual vaccine record for each individual visit.

Similarly, mothers of the chronically ill children in my practice became the trusted couriers of important office notes and lab tests between the multiple specialists who saw their children. This informal information exchange didn't replace those written physician-to-physician consultations included in my office medical records, but it did facilitate availability of these consultations to help the specialists decide what to do. Mothers never lost records.

Without this courier approach, it was more difficult to ensure the availability of the information when and where another doctor needed it. These mothers had instinctively defined the need for multiple user capability, or "interoperability," the technical term for the primary functionality in Electronic Medical Records. Medical professionals recognized the potential for EMR as far back as the 1970s, but with rapid advances in Internet technology, digital records can revolutionize the way we do medicine in the United States.

The current paper-chase method requires a mother to define multiple user input and access functionalities to accomplish what she already knows is important—timely availability of past medical history to avoid duplication of medical interventions and their unnecessary pain, complications, and costs. A real-time interoperable EMR system eliminates those racks of paper records lining doctors' offices across the country, but more importantly it would improve the quality and affordability of care from individual physicians and ensure that what goes on in one doctor's office helps the next doctor's office provide better and more affordable care.

According to a study in the Annals of Internal Medicine, physicians with paper records could perform as well as physicians with an EMR, but that study only looked at the use of an electronic record within the "silo" of a single physician's office. It did not look at the efficiency that interoperability could provide by breaking down the barriers to communication between different doctors' offices.

The promise of interoperability is its integration of electronic medical records across the health care system, from hospital to lab to primary care to specialist. This integration allows each health care provider in the chain to have accurate, up-to-date information with which to make decisions for the next step in care—and in a timely fashion without duplication or indecision on account of not knowing what happened in another office.

What's more, a key feature of an interoperable Electronic Medical Record is that it allows patients (or their mothers) to define which caregivers would get electronic access to medical information across the health system. Patients (or again, their mothers) thus have control over who sees their EMRs, which in tandem with current rules under the Health Insurance Portability and Accountability Act of 1996 governing the disclosure of private health information by medical care providers and commercial payers, goes a long way toward addressing privacy concerns about EMRs. Further steps need to be taken to ensure complete privacy protection, but these concerns should not get in the way of a much-needed EMR rollout.

Still, no digital system of care can ensure that health care providers use the information at hand unless a critical mass of providers embraces their use. Unless EMR systems are tapped for information, no interoperable system can guarantee a quality result. If we spend money on building this interoperability across the system, then how do we guarantee it will be used to its full potential?

A recent study in the Annals of Family Medicine, published in the May 2007 issue of the journal discovered just that pitfall. The study, which focused on the use of EMR in diabetes care, concluded that:

> *The use of an EMR in primary care practices is insufficient for insuring high-quality diabetes care. Efforts to expand EMR use should focus not only on improving technology but also on developing methods for implementing and integrating this technology into practice reality.*

That's why the federal government needs to take the lead in making EMRs a reality in doctors' offices across the country.

How do we accomplish this? Past changes to the health care system demonstrate that when the federal government wields its power as the largest health care payer, commercial insurers move to adopt the government standards. Case in point: Medicare adopted the Diagnosis-Related Group classification system to define the primary reason for a patient's hospital admission and determine payment. Or consider the Food and Drug Administration's guidelines for coverage of new medical-device technologies. When the FDA adopted the guidelines 30 years ago, health plans began relying on approval as the first step in determining whether commercial insurers would consider paying for the new device. In each instance, the federal government implemented a process that improved the health care system, and commercial insurers followed suit. We could expect the same with interoperable EMR.

The sooner the federal government mandates and funds an interoperable EMR platform, the sooner our health care system will start to mend in a cohesive fashion. The incentive for the federal government to do this is the enormous amount of wasted resources the Medicare system funds year after year because practice performance measurements of guideline-driven care given to chronic illness patients are not implemented.

According to a Rand Study published in the New England Journal of Medicine in June 2003, only 55 percent of patients received care according to guidelines. Whether the care is too little too late, or too much too often, resources are wasted and patient outcomes fall short. An interoperable EMR can identify where guidelines weren't being met for those patients being treated by multiple providers during the course of their illness. Each provider would have the information and could potentially improve the care if a guideline hadn't been followed. The patient could receive all the care needed, and none that he or she didn't need.

It would make your mother proud, and it could put more than just an immunization card back in her purse. sp

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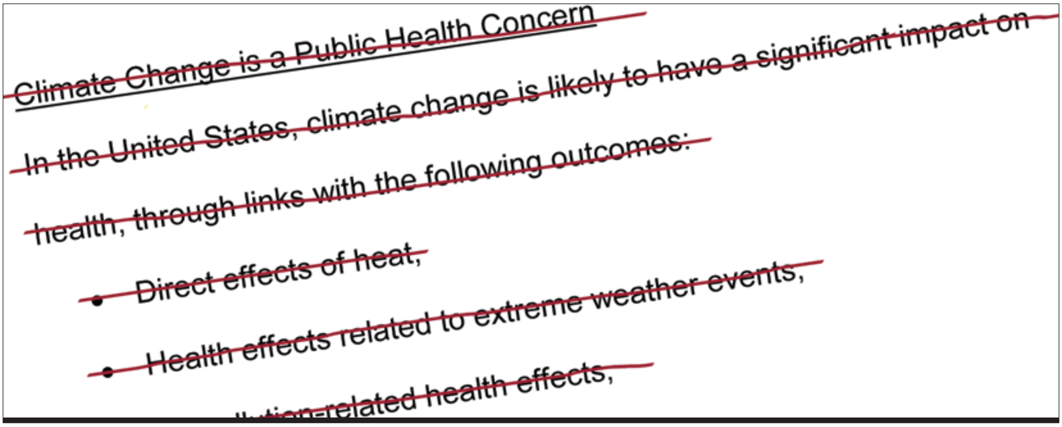
GLOBAL WARMING




# The Heat is On

## Editing of CDC Testimony Backfires

By Michael Stebbins

**A DAY AFTER HER APPEARANCE** at a Senate Committee on Environment and Public Works hearing late last year on "Examining the Human Health Impacts of Global Warming," the director of the Centers for Disease Control, Dr. Julie Gerberding, expressed deep frustration. The source of her frustration, however, was not (as most expected) the White House Office of Management and Budget for cutting half of the original testimony they received for approval. It was the journalists who reported on the massive redactions.

"I expected the press to write a lot of stories about the effects of climate change on human health and what CDC was doing about it," said Dr. Gerberding at an Atlanta Press Club luncheon. "But instead I had to read that someone had edited my testimony. I mean this is the most ridiculous thing I have ever heard."

Indeed, Dr. Gerberding is correct. The stories should have been about the potential for diseases spreading to new regions, the likely health implications of heat waves and drought as well as discussion of our most vulnerable citizens. And it is probably true that, as she put it, many in the press probably "don't really understand how written testimony occurs."

The Office of Management and Budget, of course, has every right to "try to coordinate the testimony from the administration and try to make sure that enthusiastic program directors are not trying to advocate for more money coming to their agency," she explained. But Puh-Lease, Dr. Gerberding, that doesn't make the edits made by OMB any less interesting or make them any less a news story.

In fact, the kerfuffle over the edits kept the issue in the news far longer than if the version of her testimony submitted to OMB had not been leaked to the press. The reason: The Bush administration's long track record of manipulating the science that is generated by the federal government.

Dr. Gerberding is well aware of the fact that this administration has engaged in systematic denial, redaction, stalling, and obfuscation of science findings when they don't support their ideologically driven policies, for global warming science in particular. Further, it was White House Press Secretary Dana Perino's laughable response to questions posed by the press that chummed the waters.

## MY DOG ATE IT

After initially denying that the White House had watered down Dr. Gerberding's testimony, Perino changed tack and attacked the science. Employing classic obfuscation techniques, Perino implied that the sections of Dr. Gerberding's testimony that were removed "didn't align with the IPCC [Intergovernmental Panel on Climate Change]" findings—you know, the people who shared the Nobel Peace Prize with Al Gore.

After a ladle full of those wacky science findings, Perino had almost sealed it for those supposedly lazy reporters. But then she stumbled on her punchline. "And so the decision on behalf of CDC was to focus that testimony on public health benefits—there are public health benefits to climate change."

Public health *benefits* to climate change?

To her credit, Dr. Gerberding did not focus on the "health benefits" of global warming in her oral testimony. And not surprisingly, reporters looked at the latest IPCC report and called Dr. Jonathan Patz from the University of Wisconsin at Madison, who was the lead author on three separate IPCC reports, to figure out if such discrepancies exist. Dr. Patz's response to the edits was in direct conflict with the White House's take, stating to the *The Washington Post*, "That's nonsense…Dr. Gerberding's testimony was scientifically accurate and absolutely in line with the findings of the IPCC."

Other equally qualified scientists, including Dr. Linda Rosenstock, dean of the University of California, Los Angeles School of Public Health had a similar take. Dr. Rosenstock clearly understands how public testimony occurs: "In the politicization of this topic—the science wasn't changed, it was deleted."

So who were the scientists that told the administration that Dr. Gerberding's testimony was at odds with the IPCC report? The White House Office of Science and Technology Policy, led by Dr. John Marburger, soon piped up to take some of the credit.

Spokeswoman Kristin Scuderi told *The Washington Post* in an e-mail that Dr. Marburger brought up the "inconsistencies in the use of language between the [IPCC] report and the testimony" and that "the OMB editor decided to transmit a version that simply struck the first eight pages." Consequently, a description of the current activities of the CDC focused on the most severe health consequences of global warming fell victim to the delete key of an OMB staffer who was likely unable to sift through the testimony and the IPCC report and make a determination.

## MY BAD?

The White House owes the public (as well as Senator Boxer (D-CA), who chairs the Senate Committee on Environment and Public Works and called Dr. Gerberding to testify before her committee) an explanation, and not just for this incident. The nation is in sore need of a *mea culpa* for the systematic censorship of climate science that has fueled the politicization of this issue and slowed true reform of U.S. energy policy. But such contrition has not been a hallmark of this administration, and to our detriment there is little evidence that it will ever back progressive climate preservation legislation.

The current incident has not occurred in a bubble. It is news because of a pattern of behavior, not because of a single incident of heavy-handed editing of congressional testimony. There are just too many incidents to ignore, among them:

- A political lackey who neglected to graduate from college censoring NASA scientists
- The harassing reins put on NASA scientist Dr. James Hansen
- The subtle but significant removal of "to understand and protect our home planet" from NASA's mission statement
- The failure of the Environmental Protection Agency to rule on California's request of a waiver from the Clean Air Act so they can enact a law passed two years ago to decrease greenhouse gas emissions
- The revision of news releases from the National Oceanic and Atmospheric Administration to downplay the impact of climate change
- The litmus tests for critical climate science advisory panels
- Barring U.S. Fish and Wildlife Service officials from speaking on or responding to issues relating to climate change, polar bears, or sea ice when traveling abroad.

In each of these cases, there is considerable question of whether the best interests of the country were the first priority.

In the case of Dr. Gerberding's testimony, it is at least possible that there just wasn't enough time for the Office of Science and Technology Policy and OMB to figure it out. As it turns out, they probably made a mistake. In the end, Dr. Gerberding did a fine job testifying and stated that she did not feel encumbered in her oral testimony, but her satisfaction isn't what is in question.

What is in question is whether Congress is being given the full story by the administration. Removing significant details on the full impact of global climate change is not acceptable if it was done for the wrong reason.

Congress at the time was considering over half a dozen bills for curbing greenhouse gases, including reducing emissions by raising CAFE auto emission standards. And don't forget that the committee hearing with Dr. Gerberding was in prelude to a committee vote on a carbon cap-and-trade bill that Sens. Joseph Lieberman (I-CT) and John Warner (R-VA) introduced. The bill is controversial but would also be the largest step toward controlling greenhouse gas emissions that the United States has taken to date. That bill, which will be debated on the Senate floor in June, and others before Congress are directly at odds with the Bush administration's voluntary greenhouse gas reduction policies.

Blaming the press for not covering the climate change issue well enough would have been fair five years ago, but the reporting has improved and is more focused than ever on measures to slow the consequences of global climate change. If the administration takes a few hits in the media for overzealous editing so the message stays in the public view a little longer, then maybe in some small way it will make up for some of the inaction on reducing our dependence on fossil fuels.

The Bush administration made its bed by censoring Dr. Gerberding's testimony and continually undermining efforts to understand, potentially slow, and prepare for the consequences of global climate change. The press is just fluffing up the pillows. sp

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GENETICS

ISTOCKPHOTO

# Unraveling Our Own Code

## Nancy B. Spinner on the Latest Advances in Genetics

Interview by Andrew Plemmons Pratt

**ADVANCES IN GENETIC TECHNOLOGY** move very fast. The Human Genome Project, begun in 1990 and completed in 2003, finished two years ahead of schedule, offering the first complete look at the building blocks of human life. In just the past year, researchers have grabbed headlines by completing the first sequence that encompasses the genetic data from both parents of a single individual and creating an artificial bacteria genome from scratch. Numerous start-ups are currently gunning to capitalize on the promise of personal genetic sequencing, and a \$10 million prize from the X Prize Foundation has companies racing to be the first to sequence 100 human genomes in 10 days at a cost of less that \$10,000 per genome.

But apart from this rush to capitalize on the ability to sequence genomes, scientists are learning—at breakneck pace—about the connections between the makeup of our DNA and the diseases that afflict us. A recent Associated Press article on the speed and scope of advances in the past few years quoted two Harvard scientists who wrote in the New England Journal of Medicine: "There have been few, if any, similar bursts of discovery in the history of medical research." Understanding the directions and revelations of this work will be crucial to making informed policy decisions about the future of genetic medicine and genetic privacy.

New laboratory techniques allow researchers to peer into and control smaller and smaller sequences of genes. Nancy B. Spinner, a professor in the University of Pennsylvania School of Medicine Departments of Pediatrics and Genetics, focuses her work on identifying genes that contribute to disorders like Down syndrome, in part by considering the deletions and duplications across the genomes of various individuals. Recent advances have revealed that genetic characteristics and susceptibilities to disease are not simply the product of individual genes. Rather, individuals carry different numbers of the same genes, and those extra copies—and in some cases, missing copies—of tiny genetic sequences can have serious implications for personal health.

Medical researchers may eventually be able to personalize the prevention, diagnosis, and treatment of diseases according to an individual's personal genetic makeup. Already, studies link gene variations with elevated risks of Alzheimer's disease and breast cancer. A study out just last week drew connections between genetic variation and schizophrenia.

Spinner spoke with *Science Progress* about this rapidly changing area of research and the challenges researchers face on the way to personalized medicine. This interview has been edited and condensed.

**ANDREW PLEMMONS PRATT, *SCIENCE PROGRESS*:** The latest sequencing tools for genetics research are revealing huge stores of information that go beyond identifying just the functions of individual genes. Instead, there are significant patterns in the copies of genes distributed across a person's DNA and across a population. This is called "copy number variation." Can you explain this kind of research and how it changes the way scientists are approaching genetics?

**NANCY B. SPINNER:** First let me describe my own work, which straddles the borderland between diagnosis and research, because I run both a clinical diagnostic laboratory and a research laboratory, some of what I have to say may apply to one or the other. There have been a lot of huge advances in our field—it's been a seminal time for us. The human genome sequence is known; the first draft was deposited in 2001. And we have known since around that time that there are differences from person to person. This is not unexpected, of course, because we all vary. We are all identifiable and our sequences reflect that, although it's a relatively small portion of our genomes that vary by single base changes.

But starting in 2004, we've realized that we all vary not only by those single nucleotide changes, but that there are also larger regions that can vary in copy number between "normal" individuals, who do not have an apparent genetic disorder. This was really mind-boggling, because we've known for many years—since the late 1950s and early 1960s—that there are some people with clinical abnormalities or diseases, for example, Down syndrome, where there is an extra copy of a chromosome or a part of a chromosome. Since that time, there have been many examples where missing something or having something extra causes a disease that you can understand and study. But now, we have the tools to look at small pieces of chromosomes. When we look at whole chromosomes or parts of chromosomes, we're looking at millions and millions of base pairs. Conventional cytogenetic technologies require that at least 5 to 10 million base pairs of DNA be missing or extra before it can be identified. But the new technology allows us to identify deletions and duplications as small as 5,000 bases.

We are using this new information in two ways. My lab is really excited because we can identify smaller deletions or duplications that cause disease, and so far it seems that the new technology is doubling our chance of identifying a cause for the clinical problems seen in the patients who are sent to us for testing. But at the same time, we're finding small deletions and duplications in normal people. In some cases we can be very sure which abnormalities are "disease causing" and which are normal, but in many cases, we cannot be certain. This is a huge challenge for us right now. We are also trying to understand the function and implications of these "normal" variations, and how they impact the observable differences between us, both in terms of physical features, behavioral features and susceptibility to disease. This is a huge area of research right now.

***SP*:** Besides Down syndrome, are there other diseases that your lab is focusing on in your research?

**SPINNER:** In our clinical lab, we diagnose all kinds of abnormalities that are caused by whole chromosomes being extra, as in Down syndrome. And there's a whole range of syndromes caused by deletions of parts of the genomes. My lab has focused on a disease called Alagille syndrome, which is a dominant disease that can sometimes be caused by a deletion of part of chromosome 20, and we've been studying this disease actually for 15 years now. We were able to identify the gene that causes Alagille syndrome, and we've been studying that gene. This is one of a number of different disorders caused by loss of something within the genome.

However, even in the case of Alagille syndrome, for which the disease gene is known, we're turning to studies of copy number variation to try to find out why some people who have this disease have a very mild form, while others have a very severe form. We're testing the hypothesis that some of the copy number variation that is found throughout the population might influence the severity of this disease.

***SP*:** Let's go back to your remarks on the difference between "normal" and "abnormal" genes. Research over the last few years reveals a large amount of junk DNA in our chromosomes. How much information in our DNA may not be relevant to who we are?

**SPINNER:** Sure, though I won't say that anything is not relevant. This is one of the questions that geneticists are addressing. We know there are 3 billion base pairs of DNA. That's a lot of DNA that codes for about 30,000 genes. Overall, maybe 5 percent of that DNA actually codes for the genes. When I say "genes," I'm usually referring to a piece of DNA that codes for a product, usually a protein product. So there's much of the genome that we're not completely sure what it does. But now that we know pretty much the whole sequence, we can look at variation—both in the part that is known to code for genes and the stuff that isn't known to code for genes—and we're starting to learn what's in all that stuff that we just didn't recognize before. So there is an ongoing project of the National Human Genome Research Institute called the ENCODE Project—or "Encyclopedia of DNA Elements"—and this is a consortium setting out to find out all the parts of the genome that are really crucial, that we just didn't recognize. We've gotten good at recognizing a gene. We know what its architecture looks like, and we can pretty much identify it in a rather straightforward fashion, but we don't know about all of the other parts of the genome and we're just starting to learn about those.

***SP*:** There's been a lot of coverage in the mainstream press about people being subject to genetic discrimination based on predispositions they might have. Does this new information that is coming out of research on copy number variations have implications for policy discussions?

**SPINNER:** I think it has implications, and I think there is so much to learn that it's mind-boggling. Luckily, the threats of genetic discrimination haven't really been borne out in too many cases. The genetics community is happy to see that that hasn't been as much of a problem as I think people were worried about in the beginning. The problems that are now facing us are just at the very beginning of a) understanding the variation in the genome, and b) understanding how it relates to health and disease. It is all so new that it is very difficult. The science is just not there yet, to be able to tell us what it means to have something that is extra or missing.

I'll give you an example. We are now launching a clinical diagnostic test that looks at these very small duplications and deletions. There are many labs that are already doing it, and my lab is planning to start opening the doors to take in these tests on May 1. Many researchers have been applying this to many different populations.

There was a recent study in the New England Journal of Medicine on duplications and deletions on a small part of chromosome 16 that may be associated with autism. This is one study. I don't think the data is convincing, but it is a published study in the New England Journal of Medicine. As we start running these tests clinically, we recently studied a patient—it was a research sample—and the sample was being done because the child had died of multiple congenital anomalies before birth.

So this was a serious, severe kind of abnormality. We looked at the parent's DNA, and in fact, the mother carries this duplication. There is a recent paper saying these same duplications can be associated with autism, but yet I had a family where the child had a totally different problem, had this same duplication, and the mother carries it.

So from my perspective, I'm very nervous. I don't want to overstate this relationship, I'm not convinced of it, but it's one report in a prominent journal. Anyone who Googles this will find this paper. This is just one example and shows you what happens. This is a brand-new tool. This is so new that the scientific community hasn't really had a chance to digest it yet.

We're very excited about these new tools for diagnostics, because in many cases, we're finding things we never could have seen before. The number of abnormalities that I'm convinced of has more than doubled with this new technology, so the number of patients for whom we'll be able to find diagnoses and explain what's happening and give them accurate recurrences risks is wonderful, but yet we don't completely understand the information.

***SP*:** How important is government support of basic research in genetics? What are the possibilities for creating treatment breakthroughs?

**SPINNER:** Well, you're asking a scientist, of course, so I'm biased. Most of our work is funded by the National Institutes of Health. One of the reasons why I love what I do is that I sit at this boundary. I use basic science information all the time; I do diagnostic testing; a lot of my research tends to be translational in nature. So I'm really sitting on the fence between the clinical end and the basic science end. You absolutely have to have all of those pieces in place. There's absolutely no question about it. The basic scientists who work with model organisms like yeast or Drosophila or the mouse—they can really do experiments to try to understand. Once someone like myself identifies a gene that's important in a human disease, or a region of the genome, the only way to really study it is in a model organism. So you have to have all of those tools set up and in place to do that kind of very basic science work. I think that in the human genetics world, there have been some recent advances in a couple of different diseases, for example, Marfan syndrome and Fragile X syndrome, where the information we're getting is starting to be used for treatment. I think it's a really exciting time with a lot of possibilities. As a scientist, I think it's crucial that we fund this work. We have to fund the people doing the health-related research, so they can identify the problem, and you have to fund the basic scientists. sp

CULTIVATING SCIENCE

# Engaging the Scientific Community with the Public

## Communication as a Dialogue, Not a Lecture

By Rick Borchelt and Kathy Hudson

**IN 2004 THE GENETICS AND PUBLIC POLICY CENTER** fielded a survey of more than 4,000 U.S. residents about new genetic technologies, and more than 40 percent said they did not trust scientists "to put society's interest above their personal goals." The roots of this uneasy relationship lie in the reliance that the science and technology community places in various "deficit models" of interaction with the public. The basic assumption behind these models is that there is a linear progression from public education to public understanding to public support, and that this progression—if followed—inevitably cultivates a public wildly enthusiastic about research. But this model of scientific engagement with the public obviously isn't working.

Lately, all manner of ways to "involve" the public in science policy and practice have cropped up, mostly around oversight of emerging technologies like synthetic biology, nanotechnology, and human genetics. Scientific associations are developing centers devoted to public engagement in science, funding agencies have created sweeping mandates for collecting public input on research, and research-performing institutions are hosting community meetings and science cafes about their work. But one might wonder—are these new organizations going to truly "engage" the public?

In a nutshell, an erosion of public trust that began as a trickle of doubt about radiation safety and pesticides has grown to program-threatening uprisings against emerging new technologies, from genetically altered "Frankenfoods" to concern over "grey goo" in nanotechnology.

Initially, the "deficit" in question was framed as an "information deficit"—if only lay people knew what scientists did, goes this line of thought, they too would support the agendas of the scientific establishment. Since World War II, the science community has been operating under this information-deficit model, built on one-way flow of information from the expert to the public with very little information flowing back the other way. This model drove communication of science and technology for the last half of the 20th century, despite its very obvious shortcoming: Neither public support for research nor scientific literacy increased significantly in all that time.

More recently, however, the information deficit model increasingly has been reframed as an "attitudinal deficit"—to know us is to love us, runs the mantra of this public-understanding school of science–society interaction. Having realized the practical futility—if not the ethical challenge—of making every lay person a lay scientist, the public-understanding model contents itself with pursuing public appreciation, emphasizing the benefits of science to society without worrying unduly about how much science the public actually understands.

Clearly, something needs to change in the science–public landscape.

The end goal hasn't changed—increased public support of science and technology—even if the methods used to get there and the metrics used to define success are different. The direction of information flow remains the same as well: top-down from the scientist or engineer to the public.

The asymmetric communications practices embodied by both the scientific literacy and public understanding movements cultivate scientists who resist ceding any level of control of the science policy agenda to non-scientists, a view neatly encapsulated by a quote from a series of scientist interviews we conducted at the Genetics and Public Policy Center a few years ago: "I don't think that the general uninformed public should have a say, because I think there's a danger. There tends to be a huge amount of information you need in order to understand. It sounds really paternalistic, but I think this process should not be influenced too much by just the plain general uninformed public."

This wariness is reciprocal in the 21st century, as U.K.-based communications researcher Martin Bauer and his colleagues noted in the journal Public Understanding of Science last year: "Mistrust on the part of scientific actors is returned in kind by the public." Negative public attitudes, they say, as revealed in large-scale surveys, are viewed by scientists as proof that "a deficient public is not to be trusted" to provide uncritical support for the scientific enterprise.

Clearly, something needs to change in the science–public landscape. Writing in Science in 2003, the CEO of the American Association for the Advancement of Science, Alan Leshner, summarized the problem eloquently: "Simply trying to educate the public about specific science-based issues is not working…We need to move beyond what too often has been seen as a paternalistic stance. We need to engage the public in a more open and honest bidirectional dialogue about science and technology."

Indeed, research-performing institutions increasingly say they have traded in their old, top-down models of science literacy and public understanding for the new buzzwords of "public consultation" and "public engagement." But the philosophy behind consultation and engagement seems, on closer inspection, not to have changed much at all. Many scientists expect consultation and engagement to cultivate a public more supportive of science as planned by, performed by, and promoted by scientists—despite the fact that neither consultation nor engagement have been rigorously evaluated to see if these goals are reasonable or even possible. And even if they turn out to be measurably effective in meeting some articulated goal, are they affordable enough to deploy? Neither consultation nor engagement can be done on the cheap.

What, then, can consultation or engagement do for us? This "participatory turn" in science–society relations, as Harvard scholar Sheila Jasanoff terms it, ostensibly focuses on regular dialogue (two-way, symmetrical communication), transparency of the decision- and policy-making process, and meaningful incorporation of public input into that process. On paper, the goal of these two-way, participatory models is mutual satisfaction of both parties, the research enterprise and the public, with the relationships that exist between them. Key dimensions of this dialogue are negotiation, compromise, and mutual accommodation. It places a premium on long-term relationship building with all of the strategic publics: research participants, certainly, but also media, regulators, community leaders, policymakers, and others. These emerging models offer promise for scientists and the public to engage each other more fully and productively—although the promise is as yet only tantalizing, and not yet tempered by much scrutiny from social science research.

The end game of public engagement should be empowerment.

The dearth of evaluative research on engagement stems partly from the fact that very little is being done. In practice, much communication currently passed off as public consultation and engagement is still one-way, expert-to-layperson information delivery, albeit in different settings like cafes scientifique, public meetings, and town halls. Research organizations have been quite adept at putting together well-rehearsed, tightly scripted opportunities for "public input"—but with no institutionalized mechanisms for reflecting the public's input in deliberation or policy construction. In fact, one gets the not-so-subtle impression that these engagement events are being held with the hope of staving off public dissatisfaction, or providing just enough semblance of listening to public concerns that the natives don't get so restless they revolt.

In our view, the end game of public engagement should be empowerment: creating a real and meaningful mechanism for public input to be heard far enough upstream in science and technology policy making and program development to influence decisions. It is not about making a decision among a scientific elite, and then staging public events to move the public toward agreeing with that desired outcome. It is about empowering lay citizens to learn all they want about pending program or policy issues (not what scientists believe they need to know to weigh in), and then giving them access to deliberative processes where that knowledge can be questioned, applied, and incorporated with knowledge or questions gleaned from outside the scientific process.

And it is about agreeing up front to accommodate public input politically, not just to listen and nod politely. Unlike the unidirectional and hierarchal communication that characterizes scientific literacy and public understanding models of science–society relations, public engagement practiced as iterative dialogue does result in demonstrable shifts in knowledge and attitudes among participants. At GPPC, we have documented and measured these shifts during town hall and online deliberations. But the shift is not always in the direction scientists might expect or prefer. Public engagement is not about getting the policy you want; it's about getting the public input you need to craft sustainable policy that enjoys public confidence.

Public engagement is also about agreeing up front to accommodate public input personally. Public engagement changes people. The public gains knowledge, shares expertise, and reflects on how much risk society is willing to accept to realize the promise of emerging technologies. Less appreciated, but perhaps even more significant, is the expectation that scientists who enter into public engagement should see their knowledge and attitudes change, too. This is the real mark of successful public engagement: Rather than insisting upon the public's deeper appreciation and understanding of science, its primary goal is scientists' deeper understanding of the publics' preferences and values. sp

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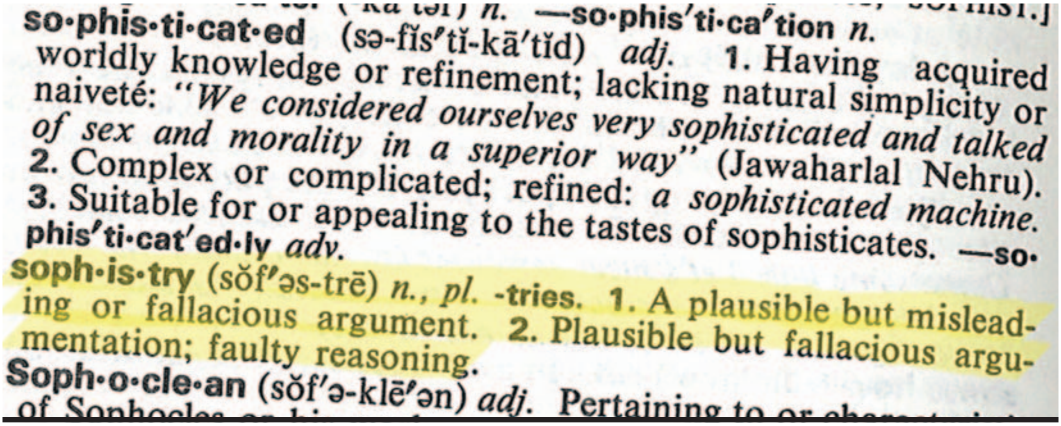
*Rick Borchelt is director of communications and Kathy Hudson is director of the Genetics and Public Policy Center at Johns Hopkins University, which is supported by The Pew Charitable Trusts with research funding from the National Human Genome Research Institute.*

COMMUNICATING SCIENCE


—so·phis′ti·ca′tion *n.*
**so·phis·ti·cat·ed** (sə-fĭs′tĭ-kā′tĭd) *adj.* 1. Having acquired worldly knowledge or refinement; lacking natural simplicity or naiveté: "*We considered ourselves very sophisticated and talked of sex and morality in a superior way*" (Jawaharlal Nehru). 2. Complex or complicated; refined: *a sophisticated machine.* 3. Suitable for or appealing to the tastes of sophisticates. —**so·phis′ti·cat′ed·ly** *adv.*
**soph·is·try** (sŏf′əs-trē) *n., pl.* **-tries.** 1. A plausible but misleading or fallacious argument. 2. Plausible but fallacious argumentation; faulty reasoning.
**Soph·o·cle·an** (sŏf′ə-klē′ən) *adj.* Pertaining to or

# Manufactroversy

## The Art of Creating Controversy Where None Existed

By Leah Ceccarelli

**MANUFACTROVERSY** *(măn′yə-făk′-trə-vûr′sē) N., pl. -sies. 1. A manufactured controversy that is motivated by profit or extreme ideology to intentionally create public confusion about an issue that is not in dispute; 2. Effort is often accompanied by imagined conspiracy theory and major marketing dollars involving fraud, deception and polemic rhetoric.*

Don't bother to look for this definition above in any dictionary because "manufactroversy" has yet to make that grade. But don't dismiss the importance of what is defined there, either, just because the word is a new invention. Manufactroversy defines precisely a rhetorical flourish in need of challenge.

Indeed, with all the sophisticated sophistry besieging mass audiences today, there is a need for the study of rhetoric now more than ever before. This is especially the case when it comes to the contemporary assault on science known as manufactured controversy: when significant disagreement doesn't exist *inside* the scientific community, but is successfully invented for a public audience to achieve specific political ends.

Three recent examples of manufactured controversy are global warming skepticism, AIDS dissent in South Africa, and the intelligent design movement's "teach the controversy" campaign.

The first of these has been called an "epistemological filibuster" because it magnifies the uncertainty surrounding a scientific truth claim in order to delay the adoption of a policy that is warranted by that science. Languaging expert Frank Luntz admitted as much in his now infamous talking points memo on the environment, leaked to the public in 2002, where he confessed that the window for claiming controversy about global warming was closing, but he nonetheless urged conservative congressional and executive leaders "to continue to make the lack of scientific certainty a primary issue in the debate."

ExxonMobil was doing this, too, when it published its "Unsettled Science" advertisement about climate science on the editorial pages of *The New York Times* in March 2000. A more recent guest editorial by a reader made the same claim in the pages of *The Seattle Post-Intelligencer* in January 2008. All three seemed to be following the playbook of the tobacco industry when scientists discovered that their products cause cancer; when a threat to their interests arises from the scientific community, they declare "there are always two sides to a case" and then call for more study of the matter before action is taken.

South African President Thabo Mbeki's support for AIDS dissent eight years ago is a similar case. Like global warming skepticism, this assault on the science of HIV/AIDS research ingeniously turned the scientific community's values against it by drawing on the importance of rational open debate, a skeptical attitude, and the need for continued research.

Mbeki alleged that the mainstream scientific community branded scientists who questioned the causal link between HIV and AIDS as "'dangerous and discredited' with whom nobody, including ourselves, should communicate or interact." Claiming the successful dissident's authority in post-apartheid South Africa, Mbeki condemned the mainstream scientific community for occupying "the frontline in the campaign of intellectual intimidation and terrorism which argues that the only freedom we have is to agree with what they decree to be established scientific truths."

A parallel case is being made by the intelligent design movement in conjunction with its "teach the controversy" campaign against evolutionary biology. Ben Stein's new movie, *Expelled*, portrays scientists as participating in a vast conspiracy to silence anyone who questions the Darwinian orthodoxy. This movie promises to be the most extreme application yet of the intelligent design movement's "wedge" strategy to break the supremacy of evolutionary theory in contemporary science.

Just as a wedge can be set into a chink in a solid structure and, with the careful application of some concentrated force, will split that structure to pieces, so too do the producers of this movie hope that it can break the scientific community and allow for a change in how science is taught in America. Of course, any claim by biologists that there is no scientific controversy to teach merely feeds the conspiracy theory.

In light of this difficulty, some have suggested that the best response to manufactured controversy is no response at all. They say that countering such nonsense merely gives these modern-day sophists publicity and enables their continued efforts to reopen debate on settled science.

I understand this impulse to remain silent in the face of foolishness, but as a professor of rhetoric, I think it's shortsighted to cede the public stage to the anti-science forces in the naive hope that no one will pay attention to them. Ever since the field of rhetoric was born, there have been those who misuse the power of persuasion to mislead public audiences, and it has been only through vigilant counter-persuasion that such deception has been overcome.

The ancient sophists, or "wise men" (wise guys?) taught the new art of rhetoric to those who would pay their fee in the 5th century BCE. They included Gorgias, who was said to have boasted that he could persuade the multitude to ignore the expert and listen to him instead, and Protagoras, who claimed that there are *always* two sides to a case and it's the sophist's job to make the worse case appear the stronger.

It was to oppose this kind of deception that Aristotle codified the art of Rhetoric in his treatise by that title. Aristotle recognized that before lay audiences "not even the possession of the exactest knowledge" ensures that a speaker will be persuasive, so he promoted the study of rhetoric so that experts could confute those who try to mislead public audiences. Today's sophists exploit a public misconception about what science is, portraying it as a structure of complete consensus built from the steady accumulation of unassailable data.

**COMBATTING MANUFACTROVERSIES**

As a scholar of rhetoric, I have studied some modern cases of manufactured controversy to discover how to best confute these contemporary sophists. The result? I have come up with some preliminary hypotheses about what makes their arguments so persuasive to a public audience.

First, they skillfully invoke values that are shared by the scientific community and the American public alike, like free speech, skeptical inquiry, and the revolutionary force of new ideas against a repressive orthodoxy. It is difficult to argue against someone who invokes these values without seeming unscientific or un-American.

Second, they exploit a tension between the technical and public spheres in postmodern American life. Highly specialized scientific experts can't spare the time to engage in careful public communication, and are then surprised when the public distrusts, fears, or opposes them.

Third, today's sophists exploit a public misconception about what science is. They portray science as a structure of complete consensus built from the steady accumulation of unassailable data. Any dissent by *any* scientist is then seen as evidence that there's no consensus, and thus truth must not have been discovered yet.

A more accurate portrayal of science sees it as a process of debate among a community of experts in which one side outweighs the other in the balance of the argument, and that side is declared the winner. A few skeptics might remain, but they're vastly outnumbered by the rest, and the democratic process of science moves forward with the collective weight of the majority of expert opinion.

Scientists buy into this democratic process when they enter the profession, That's why a call for the winning side to share power in the science classroom with the losers, or to continue debating an issue that has already been settled for the vast majority of scientists so that policy makers can delay taking action on their findings, seems particularly undemocratic to most of them.

Aristotle believed that things that are true "have a natural tendency to prevail over their opposites," but that it takes a good rhetor to ensure that this happens when sophisticated sophistry is on the loose. I concur.

Only by exposing manufactured controversy for what it is, recognizing its rhetorical power and countering those who are skilled at getting the multitude to ignore the experts while imagining a scientific debate where none exists, can scientists and their allies use my field to achieve what Aristotle envisioned for it—a study that helps the argument that is in *reality* stronger also *appear* stronger before an audience of nonexperts. sp

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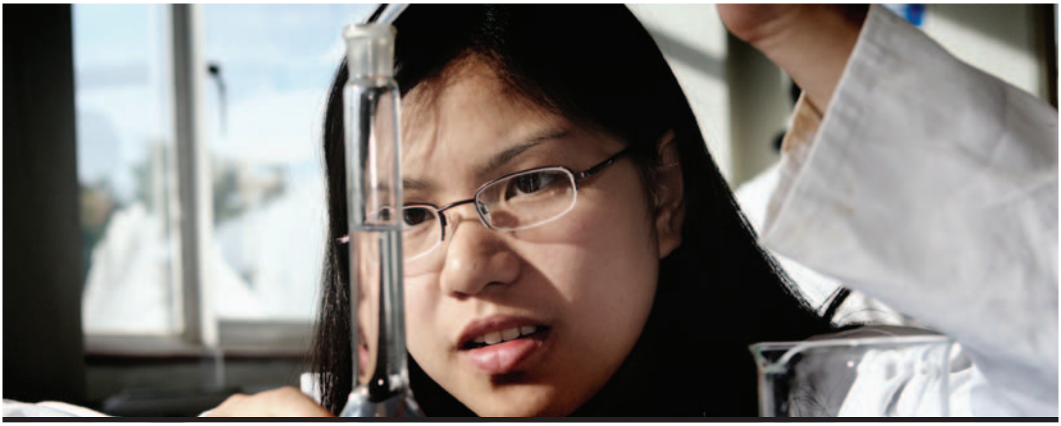
COMPETITIVENESS



ISTOCKPHOTO

# Maintaining U.S. Scientific Leadership

## English and Immigrants Are the Immediate Needs

By Richard O. Lempert

**IT HAS BEEN SO LONG** since the United States had to look up to any country in science that we Americans have come to regard science leadership as a birth right. When children in other countries score better on science tests than American youngsters or our production of Ph.D.'s and engineers or share of patent applications declines relative to other countries, we act as if the United States is slipping rather than other countries advancing, and we see a crisis emerging.

Perhaps the field we have truly fallen behind in is history. We forget that in the early 20th century German was the lingua franca of science. Germany was where young scientists went to study, and where top scientists presented, and often had done, their cutting edge work.

Far from being natural or inevitable, the United States' science leadership is an offshoot of this country's preeminence in the system of world governments that emerged after the defeat of Germany in World War II. This system was built on the rewards to science innovation in a vibrant capitalist economy, and on WWII- and Cold War-impelled needs to develop our science and engineering capacity. It uniquely benefited from immigration, especially from Europe in the Nazi era and immediate post-war period. And it could not have happened without the wealth and vision that allowed the United States to not only generously subsidize basic science but also to establish an educational system that was broad-based at the bottom and unparalleled in availability and quality at the top.

If these advantages were not enough, the competition for science leadership was weak thanks to the devastation that Europe suffered in two world wars and the slow rebuilding of European economies in the post-war era. The upshot: U.S. science leadership is not natural and inevitable, but the loss of that leadership may be.

Countries much larger than the United States, most notably India and China, are experiencing economic growth that outstrips ours, and as they grow in wealth they are rapidly improving their educational systems and basic science infrastructures. Moreover, as globalization leads companies born in the United States to move research and production capacity abroad, market demand for trained scientists and engineers is increasing elsewhere while it is being dampened here.

Even if the United States retains a per capita education and investment advantage over India and China, population differences alone mean that the number of trained scientists and engineers in these countries will soon dwarf the number in America, with differences in the quantity and quality of science innovation likely to follow. Added to the Asian challenge is a Europe that can no longer be seen as a set of discrete countries when it comes to science. Rather, cross-border research teams are being encouraged, and European Union-wide funding mechanisms are being established.

In short, several decades from now we may find that we are not the world's number one country when it comes to science, however measured, but perhaps no. 4 behind China, India, and the EU. We may also find that being in fourth place is not altogether bad. When children in China are vaccinated against polio, they are not worse off because the vaccine was invented in the United States. When an Indian inventor draws on two decades of U.S. government-funded research to achieve a technological breakthrough, her accomplishment will not be lessened because it would not have happened had research in the United States not paved the way.

As the world no. 1 in science, U.S. science investments have had substantial spillover effects, improving the quality of life in other countries and enabling scientific, technological, and medical accomplishments that have benefited people abroad. As other countries improve their science, the progress of American science and the lives of our people will increasingly benefit from educational and infrastructure investments made elsewhere and from research supported by currencies other than the dollar.

Acknowledging the inevitable and seeing a bright side does not, however, mean we should regard what is happening as an unalloyed blessing and passively allow American science to slip. There are substantial costs should U.S. science capacity sink absolutely, and real costs even if slippage is only relative. Scientific advances create intellectual property, and wealth creation through intellectual property has become an increasingly important part of the U.S. and world economies. What's more, the world remains a dangerous place, and it may become more so should countries like China develop expansionist ambitions. Science for security must remain a high national priority, and although we may not be able to keep other nations from catching up, we do not want to be surprised by their achievements or surpassed.

In devising policies to maximize the strength of U.S. science, our nation has two unique resources it must not squander. The first is English. Thanks to the preeminence of U.S. science for more than half a century, English is second only to mathematics as the universal language of science. Scientists around the world speak and write English. This gives American scientists a leg up in communicating with scientists across national boundaries and makes many of the most important writings of foreign scientists easily and immediately accessible to Americans.

Additionally, American students are not dissuaded from pursuing science careers nor do they have their science studies delayed because of the need to master a foreign language. Short of eliminating federal science funding, nothing, I venture to guess, would harm American science as much as a need to read Chinese to keep up with the latest science developments.

One goal of our national science policy should be to maintain English as the global language of science. This might entail subsidies or other incentives to promote the publication of English-language online science journals, aid to enable the acquisition of English-language science materials (including print journals) by universities and libraries abroad, and programs to train foreign scientists in English, either in their own countries, online, or by bringing them to the United States or Britain for science internships or language instruction.

The high subscription price of leading English-language science journals is a particular threat because it means that for financial rather than science reasons market forces are likely to promote a proliferation of lower priced foreign-based journals in languages other than English. These journals, started for reasons of cost, may become science journals of record in their home countries, meaning that cutting-edge overseas research may become less easily or immediately available here. The short-run solution may be U.S. subscription subsidies for foreign scholars and institutions, but the only viable long-term solution is to bring costs down, most likely by electronic distribution that through competition reins in the profit-oriented publishers who now mediate between the creation and distribution of science knowledge.

The United States' second great advantage is our system of higher education. We are still the preeminent nation when it comes to science training, and we benefit from this in many ways. Foreigners who come to study here learn English, and they build relationships with U.S. scientists that endure after they return home, if they return home. Study here can also lead to an appreciation for the United States and its values, including especially the values of democracy and free inquiry. Perhaps most beneficial of all are the foreign-born scientists who stay to take jobs here or who return periodically to work collaboratively with U.S. scientists. They add to our science workforce and scientific productivity and go a long way to make up for inadequacies in the production of U.S. born scientists.

Ironically, the threat to U.S. science dominance is in part due to our willingness to educate the world. Some of the foreign scientists trained here have returned home to become leading researchers or educators in countries such as India and China, while others have returned to Western Europe and reinvigorated their graduate science education. Thus, our leadership in science education, although not as vulnerable as our overall science leadership, is also ripe for challenge.

Rather than rise to the challenge, however, we have aided the challengers. Short-term political and security concerns have trumped longer-term interests in science strength along with longer-term wealth and security. Responding viscerally to the attacks of 9/11, we made entering this country more difficult for foreigners whatever the reason. One result was that students who had planned on doing their advanced science studies in the United States went instead to Europe, Australia, Japan, or Canada. Or they pursued advanced degrees in their home countries.

More recently, the Iraq war and attitudes toward immigration have made the United States less attractive to educated foreigners. Difficulties in entering the United States have also affected the location of and attendance at scientific conferences as well as the ability of universities and companies to employ foreign researchers. Although the U.S. government has become sensitive to the harms that some of its post 9/11 policies caused and has tried to ameliorate problems, it could be doing much more—including proactively encouraging more foreign students to study science here and making it easier for them to work here when their studies are concluded.

The downside of replenishing our science workforce with the foreign born is that it diminishes pressure on industry and government to stimulate domestic science training. Yet few dispute that improving domestic education must remain a high priority, especially as opportunities for science workers abroad grow sufficiently attractive as to not only lure foreign-born U.S. science workers back to their home countries, but also to entice native-born American scientists to work abroad.

Essays, and indeed books, can and have been written on what stimulating domestic science training will take, and I shall not attempt to canvass the suggestions that people more knowledgeable than I have made. But I will reiterate one point. We cannot afford to leave undeveloped the talents of minorities and the poor by failing to provide the nutrition, health care, preschool training, and later education that will allow these youth to realize their potential. It is no longer just personal accomplishments we are talking about; it is the national well being.

A virtue of science progress is that it cannot help but create free riders. New discoveries and inventions fuel other new discoveries and inventions and raise everyone's quality of life. Even if intellectual property laws allow innovators to secure fortunes for themselves, exclusive rights last only for period of time, and rarely can all profits be captured. We, along with other nations, are made better off by new vaccines discovered in Britain, cell phone technologies born in Finland, robotics breakthroughs from Japan, and the development of disease-resistant plant varieties in the United States.

Americans love to rank things, whether it is football teams, law schools, or most livable cities, and we love to identify with or be "Number One." For many it is a matter of national pride that the United States is acknowledged as the world's leader in science. Hence it is a matter of great national concern when it appears other nations are catching up or that we may be slipping. But the two ways of reducing disparities in the rankings are quite different.

If other nations are doing better in supporting science and producing more scientific breakthroughs, then we are likely to benefit from their successes. But if our lead is slipping because we are losing capacity and failing to invest in the physical and human capital that produces outstanding science, then there is substantial cause for concern; not only the United States but the world will be worse off as a result. In short, we should focus more on how we are doing and spend less time worrying about whether other nations are catching up to us in science.

If our youth are well-educated in science, if our science workforce has the highly trained staff it needs, if we facilitate the international exchange of scientific knowledge, and if our educational establishments and industry remain fountains of innovation, then we need not worry whether other nations are doing as well or better than we are. We will be strong. But if our lead is lost because we squander our advantages and fail to educate our youth, then slippage in the ranks of nations doing science may indeed signify crisis. sp

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SCIENTIFIC INTEGRITY

ISTOCKPHOTO

# Yes, Virginia, There Is a War on Science

## Conservative Attempts to Argue Otherwise Have Been Feeble

By Chris Mooney

**I HATE TO CONFESS IT,** but lately I've been feeling a bit wistful for the arguments of conservative science pundit Tom Bethell, author of the 2005 polemic *The Politically Incorrect Guide to Science*. Granted, the "Incorrect Guide to Science" would probably have been a more accurate title, in that Bethell is just plain wrong about everything from evolution (which he tries to debunk) to global warming (which he argues isn't human-caused) to African AIDS (which, shockingly, he calls a "political epidemic").

Yet despite such outrages, there's something bracingly honest about Bethell's book—he really *doesn't* accept mainstream science on many issues, and so he tries, very straightforwardly, to argue that his facts are right and everybody else's are wrong.

A new wave of conservative science punditry—epitomized by an essay by Yuval Levin in *The New Atlantis* entitled "Science and the Left," which was itself recently publicized by former Bush speechwriter Michael Gerson in an oped in the *The Washington Post*—demonstrably lacks such candor. Setting out to debunk the idea that there really is a "war on science" coming from the right, these writers don't bother engaging on the facts of the case at all. They don't attempt to show that, say, conservative anti-evolutionists are right, or that conservative global warming deniers know what they're talking about.

Instead, Levin and Gerson ignore, trivialize, and even mock the very serious argument that scientific information has been systematically mistreated under this administration and by the American political right. Here's Gerson: "There are few things in American politics more irrationally ideological, more fanatically faith-based, than the accusation that Republicans are conducting a 'war on science.'"

As for Levin: "Beneath these grave accusations, it turns out, are some remarkably flimsy grievances, most of which seem to amount to political disputes about policy questions in which science plays a role."

And that's it for these authors—rather than taking apart the "war on science" argument, they simply assert with a wave of the hand that we're all confused, that the facts of science aren't under attack from the right, it's just that disagreements have occurred over ethics and policies. But of course, that's hokum.

As the author of the original book making this argument—*The Republican War on Science*—I took pains to show that in each of my case studies, the scientific information itself was under attack. And as for the literally hundreds of scientists employed by this government who have now been shown, in successive surveys conducted by the Union of Concerned Scientists, to have experienced political interference in their work? Once again, these scientists trade in facts, analysis, and expertise. They know the elementary science–policy distinction as well as everyone; as government researchers they live and breathe it. They're *still* outraged.

For Levin and Gerson, though, dismissing concerns about a conservative "war on science" just serves as a springboard for another offensive—trying to show that the political left's loving embrace of science might well lead it off a cliff. Levin rightly observes that there's something in the spirit of modern liberalism that grows out of the scientific revolution of the 17th and 18th centuries, which unleashed a profound distrust of hoary old authorities and empty traditions (especially religious ones). Levin even admits: "The left is therefore generally justified in thinking of itself as the party of science." (Why, thank you.)

But that's just a set-up: Levin's lengthy essay (parroted by Gerson) proceeds to argue that the liberal embrace of science engenders two key conflicts—one, with its support of environmental values, and second, with its support for equality. Science, according to Levin, can undermine both.

But the arguments adduced to show this hardly withstand scrutiny. True, in the European green movement we do see a rift between science and a value system rooted in the desire to preserve the authenticity of "nature"—hence the sabotaging of biotech crop fields. But this case notwithstanding, there are many more ways in which science *bolsters* the environmental cause—most obviously, by allowing for the serious and detailed analysis of environmental impacts and problems.

Environmental scientists, based at universities across the country, hardly see any conflict between the two chief words that describe their professions. What does irk them, however, is to conduct a painstaking study of an environmental problem, only to find some industry-funded scientist with the gall to assert that their facts are wrong—and then to further watch that industry-funded scientist get pulled before Congress by conservatives to testify, or get used by the Bush Office of Management and Budget to torpedo a proposed environmental regulation.

But then Levin strays still farther, arguing that some fundamental conflict exists between the liberal embrace of science on the one hand, and the liberal concern for preserving equality on the other. You'll only follow Levin down this road if you share a key assumption—that abortion, in vitro fertilization, and genetic pre-screening constitute a "new eugenics," which I certainly do not. *Science Progress*'s Jonathan Moreno has already taken apart Gerson's (er, Levin's) clumsy attempt to draw an analogy between old eugenics and "new," pointing out that progressives were among the strongest critics of the old eugenics, and that some conservatives continued to embrace eugenics even after WWII.

But let me just explode one of Levin's additional assertions. "Science, simply put," he writes, "cannot account for human equality, and does not offer reasons to believe we are all equal. Science measures our material and animal qualities, and it finds them to be patently unequal." Oh, really? What more equalizing force could there be than a book like Jared Diamond's *Guns, Germs, and Steel*, which shows that racialist theories cannot explain how it is that Europeans managed to take over virtually the entire Earth—rather, distinct environmental and technological advantages made all the difference. Score one for science, and one for equality at the same time.

In the end, Levin and Gerson (who just does the Cliff Notes version) fundamentally ignore the assault upon scientific conclusions and expertise that now exists, and that emanates largely, in this country, from the political right. Instead, they seek to turn the tables and depict science as a kind of Kryptonite for the political *left*, because it undermines some of our core ideals. But that's just wrong—science helps advance and strengthen those ideals.

Finally, then, Levin and Gerson don't just conveniently ignore the core of the "war on science" argument; they also creatively redefine liberal ideals and values so as to create greater tensions between them than actually exist. Fundamentally, they're ignoring the truth about what progressives think and argue—and thus, unfortunately, engaging in still more conservative obscurantism. sp

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NEW FRONTIERS

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# It's Just Like That, Except Different

## The Power of Analogy In Describing Nanotechnology

By W. Patrick McCray

**HISTORICAL ANALOGIES HAVE POWER.** Is Iraq circa 2008 like Southeast Asia in 1968? Can one think of the United States, as Cullen Murphy suggests, as an imperial power whose recent history and future fate compares with ancient Rome? Historical analogies help frame policy debates and, while they do not establish proof, they suggest possibility. For the broader public, analogies also generate useful connections and relations, emotional as well as logical. At the same time, false or poorly constructed analogies can promote misunderstandings and even bad policy.

When it comes to understanding emerging fields such as information technology, biotechnology, and nanotechnology, historical analogies are just as potent. They help shape debate and can validate, even suggest, possible futures. In the 1960s, as the United States and the Soviet Union raced to best each other with feats in space, historians debated over whether comparisons to 19th century railroad infrastructure could help society prepare for the shocks that robust programs of space exploration would surely bring. In 1962, in fact, NASA sponsored a project that encouraged scholars to consider the long-term implications—economic, political, and social—of the national space program.

When it comes to understanding potential societal and environmental implications of nanotechnologies, the historical analogy invoked most often by both nano-advocates and opponents is that of genetically-modified organisms. According to Kristen Kulinowski and Vicki Colvin of Rice University, GMOs followed a "wow to yuck" trajectory. Initially hailed as a solution to issues such as world hunger, activists saddled GMOs with a negative public image, criticized them as destructive to the environment, and condemned genetically engineered crops for the harm they might visit on the public and developing world farmers.

The GMO-nano analogy, however, is historically inaccurate. The history of GMOs and the accompanying controversy cannot simply be reduced to a "wow to yuck" story in which public backlash derailed a promising industry or product. In reality, considerable ambivalence and critical debate about genetically engineered organisms existed from the technology's very beginning. Moreover, people hold food in a much different regard than, say, sunscreen or carbon nanotubes for high-tech television displays. We deliberately eat food; we don't ingest nanotech stain-resistant pants. By the same token, GMOs are developed for deliberate release into the environment, which is generally not the goal of most nano-oriented R&D. So while the comparison between GMOs and nanotech can help us understand some policy debates about social and environmental implications, other historical analogies would better inform policy debates and public understanding.

Another analogy that could help us understand the U.S.'s National Nanotechnology Initiative is the history of NASA's space program. (Since 2000, the NNI has been this country's multi-agency, multi-billion dollar nanotech program.) While not perfect, the analogy between the NNI and the formation of our national space enterprise provides several valuable points of comparison which might help us understand the nature of nano-research beyond the point where GMO/biotech association fails.

Like the space program, the NNI was conceived out of a spirit of competitiveness. Like competition with the Soviets through the long twilight struggle of the Cold War, concerns that the U.S. was slipping economically relative to European and Asian countries helped foster support for the NNI. One aspect of the NNI that has received robust funding support has been the creation of national research centers—the NSF alone funds more than a dozen such sites devoted to research and public engagement—just as the flood of NASA-directed funding helped spawn a whole host of 60s-era federal and university research centers for space science and exploration.

Like space science, nanoscience research is, in principle, highly interdisciplinary, bringing together scientists and engineers from fields such as biology, chemistry, and solid-state physics. NASA itself funds four such nano-research centers, suggesting the continuation of a decades-old trend. And just as space science research in the 1960s influenced pedagogy and student training, today's courses for budding nanotechnologists reflect a "new" hybridized approach to science education. While some skeptics have argued that the NNI's focus on practical (i.e. commercial) applications has distorted traditional university-based research and education, the fact remains that much of 1960s space science research was done both to produce new knowledge and to get the U.S. to a clearly defined place such as the Moon or an orbit around Mars.

Broaden the view and more similarities snap into focus that suggest the power of the space-nano analogy. In 1926, the Russian space visionary Konstantin Tsiolkovsky wrote "First, inevitably, the idea, the fantasy, the fairy tale. Then, scientific calculation. Ultimately, fulfillment crowns the dream." Whether or not today's nano-advocates wish to admit it, the fact is that an aura of the fantastical has surrounded nanotechnologies since the 1980s. As late as 2000, Nobelist Richard Smalley of carbon nanotube fame was still recommending K. Eric Drexler's 1986 techno-utopian *Engines of Creation* to government policy makers curious about what nano could do. Like the space frontier, advocates depicted the nano-frontier as the place where America's manifest destiny in science and technology would next unfold. In congressional testimony, Smalley even invoked powerful imagery from the Apollo era, saying that what was needed was someone bold enough to "put a flag in the ground and say: 'Nanotechnology, this is where we are going to go.'"

While such historical analogies can help us understand the past, and perhaps even the present, can they tell us anything about the future of emerging technologies? The now-comical phrase "power too cheap to meter" alone should be enough to induce caution when it comes to making predictions about future technologies. However, one can consider the directions the space program took after the Apollo era concluded and inject a note of caution for the U.S. nano initiative. To a large degree, as historians like Howard McCurdy have argued, NASA's public policies were shaped by the public's imagination as to what space exploration would be like. This entailed a strong focus on human (versus robotic) space exploration, elaborate manned space stations, and, eventually, bases on the moon and Mars. As satellites and space travel became routine, the Apollo era gave way to less exciting space shuttle flights and space probes that, while yielding tremendously exciting scientific information and inspiring vistas, did not have the same hold on the public's attention as did the first Mercury flights or Apollo 11. As one NASA official put it, "We don't give ticker tape parades for robots." Ultimately, NASA's grand ambitions were re-directed from the initial vision that many citizens found so compelling. How will the public react when it doesn't get the nanobots or molecular assemblers that early visionaries first proposed and which were so widely promoted in hundreds of newspaper stories and popular science magazines?

Today, it is almost a cliché for science policy makers to call for another Apollo or Manhattan Project-style effort to address pressing energy needs or global warming. We must carefully choose an appropriate historical analogy in framing these suggestions, however. What policy maker would want to initiate a program that eschews long-term goals for a single spectacular feat or develop a technology under classified, wartime conditions and not fully consider its potentially profound social and ethical implications?

While invoking the Apollo era may conjure nostalgic visions of America's past and what was right about the country at the time of great social unrest and an unpopular war, it should not be the pole star by which science policy navigates. When considering the implications of emerging technologies like nano, the power of historical analogies to shape discourse, frame media coverage, and inform the public demands more careful and reasoned attention. sp

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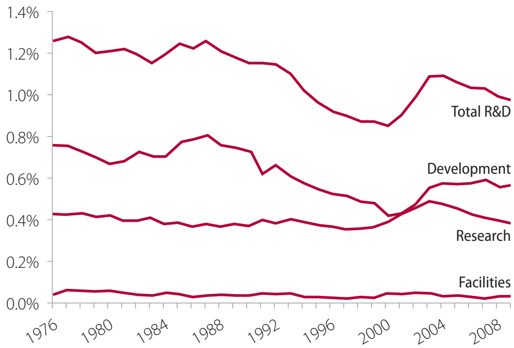
# Federal Support for R&D

**EVERY CONGRESSIONAL BUDGET** brings new questions about how much support the government will provide for research and development in science and technology. To understand the context for current funding discussions, it helps to have the long view. But the key question, as Daniel Sarewitz, director of the Consortium for Science, Policy, and Outcomes at Arizona State University, pointed out in a summer 2007 article in *Issues In Science and Technology* is not just "how much" but "what for." Here's a snapshot of federal funding over several decades, with a close-up on the last congressional budget cycle for fiscal year 2008.

**Trends in Federal R&D as Percentage of United States GDP, FY 1976–2009***

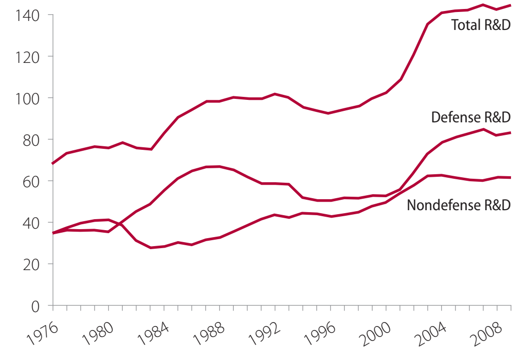



*FY 2009 figures are latest AAAS estimates of FY 2009 request.
Redrawn from AAAS R&D reports: http://www.aaas.org/spp/rd/09pch2.htm.

## Government investment in R&D is shrinking relative to the size of the economy

Federal support of research and development as a proportion of U.S. gross domestic product is trending downward. Increases in Department of Defense weapons development have buoyed numbers in recent years, but non-defense spending has shrunk as a share of GDP since the end of the five-year push that doubled the National Institutes of Health budget from 1998 to 2003.

**Trends in Federal R&D, FY 1976–2009***
**(in billions of constant FY 2008 dollars)**




*FY 2009 figures are latest AAAS estimates of FY 2009 request.
Redrawn from AAAS R&D reports: http://www.aaas.org/spp/rd/09pch2.htm.

## More dollars, but insignificant growth

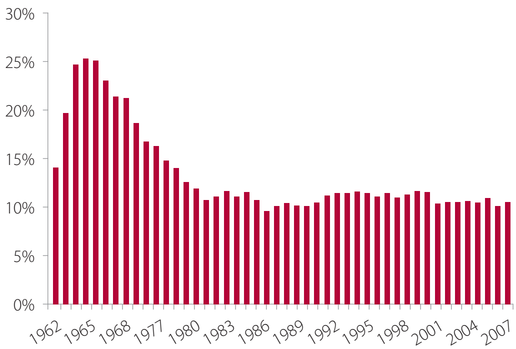
President Bush's budget request would put federal R&D spending at $147.4 billion, a record high. Again, much of the increase in recent years has gone to defence development while non-defense spending has remained relatively flat. Funding for the NIH has been flat since 2003, and accounting for inflation, the agency's real buying power has declined 6 percent.

## Funding trends do no meet the challenges of our current era

In fact, the share of non-defense federal funding that goes to R&D has remained relatively flat since the final Apollo mission in 1975.

Writing on the fiftieth anniversary of the launch of Sputnik, Vint Cerf, Google Vice President and Chief Internet Evangelist, described a "A New Scientific Resolve" in a *Science Progress* column: "Fifty years ago the United States rose to the challenge. Similarly, resources dedicated today to the challenge of global warming will ensure innovation continues to flourish across our planet." That will require more federal funding.

**Non-Defense R&D as a Percentage of Federal Non-Defense Discretionary Spending, FY 1962–2007**




Redrawn from Daniel Sarewitz, "Does Science Policy Really Matter?" Issues in Science and Technology. Summer 2007. From AAAS historical funding tables.

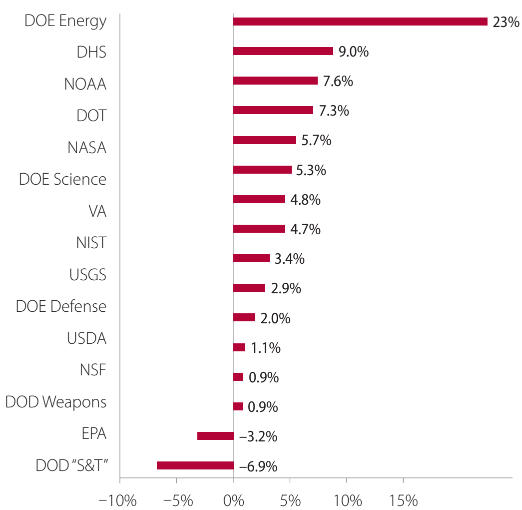
## Crucial increases are not happening

In December 2007, after multiple continuing resolutions, Congress passed and the President signed an omnibus spending package. Increases in funding were modest for most federal research agencies. Overall, federal support for R&D declined for the fourth year in a row.

The budget did contain key boosts for Department of Energy research–a crucial area of work as we move the country toward a low-carbon economy.

In their report, "A National Innovation Agenda," *Science Progress* Advisors Tom Kalil and John Irons recommend boosting the R&D budgets for the NIH, the National Institutes of Standards and Technology, the Department of Energy Office of Science, the DOD, and the National Science Foundation by ten percent a year over ten years. Unfortunately, there's ground to be made up after 2008.

**R&D Appropriations in FY 2008 Omnibus**
**(percent change from FY 2007)**




Redrawn from AAAS estimates of R&D in FY 2008 appropriation bills: http://www.aaas.org/spp/rd/upd1207.htm.

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**OUR ONLINE MAGAZINE** provides weekly commentary and analysis at the intersection of science, policymaking, and innovation, alongside the monthly posting of new in-depth reports.

ENGINEERING

**Catching Crumbling Infrastructure**

The Minneapolis bridge collapse underscores the need to modernize infrastructure monitoring, reports **Reece Rushing.**

DEFINING SCIENCE

**Science, Delayed**

by Chris Mooney

The quest to restore dedicated science advice for Congress through a reborn Office of Technology Assessment has proven more difficult than one might have supposed.

FINANCING SCIENCE

**Reopening the IPO Window**

by Joseph Bartlett

Without greater access to public markets, startup entrepreneurs trying to commercialize cutting-edge science and technology will founder.

LIFE SCIENCES

## Synthetic Life: Should We Do It?

### The Ability Is Only Decades Away

SOURCE: USDA

Creating life in the laboratory is an inevitable scientific milestone, which means we need to discuss safety issues and other repercussions now. Above, E. Coli bacteria, the "lab rat of microbiology," under intense magnification.

By David W. Deamer | Thursday, December 13th, 2007 | Share This | Print

In Mary Shelley's classic tale, Dr. Victor Frankenstein assembled a human body from parts retrieved from corpses. The novel, first published nearly two hundred years ago, raised questions that we would now consider to fall within the realm of bioethics. In fact, if Frankenstein wanted to carry out his experiment today he would need to bring it to the attention of the Institutional Review Board at his university, which would doubtless reject it.

Yet a number of laboratories around the world are attempting to perform a reconstitution of life eerily similar to Frankenstein's dream, but on a microscopic scale. There is even a name for such science: synthetic biology.

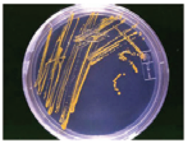
The history of attempts to fabricate artificial cells that increasingly are approaching the definition of living organisms is complex, compelling, and most of all fast-moving. These efforts have not yet succeeded, but there is reason to believe that the goal may be achieved in the next decade. When someone somewhere on Earth announces that they have been successful, significant public concerns will arise in terms of safety issues, but also because success will challenge deeply held religious beliefs that the synthesis of living organisms should be reserved for a Creator.

Without a grasp of the science itself any discussion of the policy implications of synthetic biology would be ill-informed.

Before delving into these serious safety and ethical issues, however, we first need a quick history of synthetic biology to date. The reason: without a grasp of the science itself any discussion of the policy implications of synthetic biology would be ill-informed.

## Science Progress Blog

### The Dish: Sampling Today's News - January 18, 2008



Scientists have produced a new tool that could potentially **combat vitamin A deficiency** in developing countries. The new system will allow analysis of a corn crop's genetic make-up to identify and cultivate the breeds with high levels of vitamin A precursors. Vitamin A deficiency causes eye disease in about 40 million children a year and poses health risks to another 250 million people around the world. The analytical tool could help hundreds of millions of people who rely on corn as an essential part of their diets.

Private and public research institutions and publications are struggling to adapt to demands for transparency and popular participation. The Columbia Journalism Review's Observatory yesterday reviewed various experiments in **open and participatory publishing,** including a recent effort in the pages of Scientific American and the experiences of various blogging communities. Christie Nicholson, the community editor for Scientific American, said she would like to develop a new platform that is "not quite wiki, but more than commenting." Scientists and science communicators working in this new field, dubbed "Science 2.0," gather today and tomorrow in the Research Triangle at the 2008 North Carolina Science Blogging Conference (scienceblogging.com).

Google follows through on its promise to investors with a $25 million gift to an array of projects that include tracking global health risks to aiding the poor in India. When the company went public, it pledged to **donate one percent of its profits and equity** to "making the world a better place." The company will offer grants and make investments of $175 million over the next three years under its philanthropy wing, Google.org. The approach is distinct in that the company will invest in for-profit ventures, allow Google employees to get involved directly, and even lobby public officials for policy changes.

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