



RAND

***Science and Technology
Policy Institute***

A Report to the
President: Analytic
Perspectives on
the Science and
Technology Issues
Facing the Nation

2001

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S&TPI Publications

The Science and Technology Policy Institute provides its technical and analytical support to the White House Office of Science and Technology Policy (OSTP) and to federal agencies through a variety of mechanisms. These include informal discussions, formal briefings, short written reports, detailed reports published in book form, Web sites, and CD-ROMs. Often, a mix of mechanisms is employed for a particular project, with the final results published in a publicly available report. Throughout this publication, there are lists of publicly available documents that S&TPI has produced during the course of its work for OSTP and various government agencies. Also listed are other RAND reports that are relevant to science and technology policy.

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Director's Foreword

Advances in science and technology contribute to America's economic growth, quality of life, and national security. Many of these advances flow from government activity—spending on research and development (R&D); fostering an environment conducive to innovation; and convening the public, private, and academic sectors to work toward a common goal. Making wise decisions about science and technology policy choices is a key to achieving national goals in myriad sectors, from health and education to national security and the uses of outer space.

Many of these decisions take place within individual agencies and relevant committees of Congress. However, some are of such importance and political salience that they demand the attention of the Executive Office of the President. While most presidential decisions are in essence political matters in that they take into account a wide range of considerations, they must rely on a solid understanding of the consequences of alternative courses of action if they are to be effective. This understanding in turn requires expert analysis of the scientific and technological dimensions of the issues in question and of the economic and social impacts of alternative policies.

The Science and Technology Policy Institute (S&TPI) at RAND is chartered by Congress to play a central role in conducting analysis to support presidential decisionmaking that affects science and technology. We inform policy decisions within the Executive Office of the President and across agencies of government on issues relating to science or in which technological devel-

opment figures prominently. We do this by applying RAND's strengths—objective, independent analysis—to help inform decisionmakers at the highest levels as they frame and implement policy.

No other policy research organization has this important mandate or plays this crucial role. Over nearly a decade of fulfilling this role, S&TPI has developed a core set of capabilities and has used it to address imperative policy issues. Based on this experience, we judge that the need for this mission continues to grow as the U.S. science and technology enterprise becomes more complex, more interdisciplinary, and more international.

Under the new director, Helga Rippen, who assumed the post in Fall 2001, the Institute will continue to pursue its vital mission.

This Report to the President, mandated by the legislation governing S&TPI, presents some of the key findings resulting from our activities. We present these in a format intended not only to report on our activities but also to communicate what we have found to a wider audience and to prompt more general discussion of effective policymaking in this realm of public concern.



BRUCE DON

Director, FY1996–2001

Science and Technology
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Mission Statement

Originally created by Congress in 1991 as the Critical Technologies Institute and renamed in 1998, the Science & Technology Policy Institute is a federally funded research and development center sponsored by the National Science Foundation and managed by RAND. The Institute's mission is to help improve public policy by conducting objective, independent research and analysis on policy issues that involve science and technology for the White House Office of Science and Technology Policy and other federal agencies.

Meeting the Need

Helping Improve Science and Technology Policy Decisions

The Science and Technology Policy Institute (S&TPI) at RAND conducts research and analysis on policy issues related to science and technology for the U.S. government. Established by Congress in 1991, it is a federally funded research and development center overseen by the National Science Foundation (NSF). S&TPI's congressional charter specifies a clear mandate—to provide independent, objective analysis to support the White House Office of Science and Technology Policy (OSTP) and other govern-

ment decisionmakers as they consider key policy decisions involving science and technology.

The United States needs analytic thinking and advice to illuminate the implications of the quickly changing landscape created by advances in science and technology. This idea is not new. Indeed, science and technology advisors for the White House can trace their predecessors back to the 1800s, and most other developed countries have institutes similar to S&TPI. But what is new is the nature of the research and analysis applied to meet the need. Incorporating not only scientific and technical knowledge but also such diverse disciplines as economics, statistics, computer science, risk analysis, organizational theory, and cost-benefit analysis, S&TPI provides a unique perspective for policymakers. Through this policy-analytic research and through the consultation activities it conducts within a national and international framework, S&TPI identifies opportunities, explores the implications and consequences of policy decisions and scientific advances, and evaluates the impact of government programs.



S&TPI often acts as a gateway into RAND for international cooperation. Here, Michael Rich, RAND's executive vice president, and the S&TPI leadership team meet with Dr. Kwang Nham Kang, president of STEPI, S&TPI's sister organization in Korea.

It helps to improve decisionmaking through direct advice and analytic rigor in a timely fashion.

The congressional charter for S&TPI also requires that “the Institute shall submit to the President an annual report on the activities of the Institute under this section.”¹ This Report to the President was produced, in part, to satisfy the statutory requirement. It is a formal report of activities, findings, and expertise. But it is also intended to be more. The very nature of S&TPI’s mission means that the problems it is asked to address are issues of national concern, necessarily reaching into the deliberations of the nation’s foremost public authorities. Such problems invariably affect a wide range of private concerns as well. Therefore, we further intend through this report to bring the findings from S&TPI studies and activities to the attention of a wider public. We aim to improve the quality of public discussion on issues of national importance in a manner consistent with the fundamental charter of RAND itself.

In its early years, RAND pioneered several analytic methodologies—linear and dynamic programming, mathematical modeling and simulation, network theory, cost analysis—that are now essential features of the policy analyst’s tool kit.



RAND’s JOHNNIAC was the first on-line, interactive computer system.



In the realm of science and technology, RAND researchers made seminal contributions to digital computing and artificial intelligence:

- RAND developed the first on-line, interactive computer system, the JOHNNIAC Open Shop System. This system was part of RAND’s work to provide the Air Force with a national communications network.
- RAND analysts laid groundwork for America’s space program by developing the first successful reconnaissance satellites and creating a capability for mapping the moon and several planets in the solar system.
- RAND researchers developed a series of analytic techniques ranging from the “Delphi” method of obtaining expert consensus on highly uncertain future developments, to the Linear Programming and Dynamic Programming techniques for solving complex mathematical problems.
- RAND integrated these new tools and techniques into “systems analysis,” a way of identifying and often quantifying the consequences of policy options that enables decision-makers to see the whole picture.
- RAND developed a technique known as “packet switching” to help the Air Force develop fail-safe communications programs that could survive a nuclear attack. Packet switching relays information across computer networks. Its technology provides the foundation for today’s Internet.
- RAND developed RaDiUS, the first comprehensive database of federal spending on research and development.

¹ 42USC6686(e) “Annual Reports.”

RAND: Applying Analytic Tools to Policy Problems

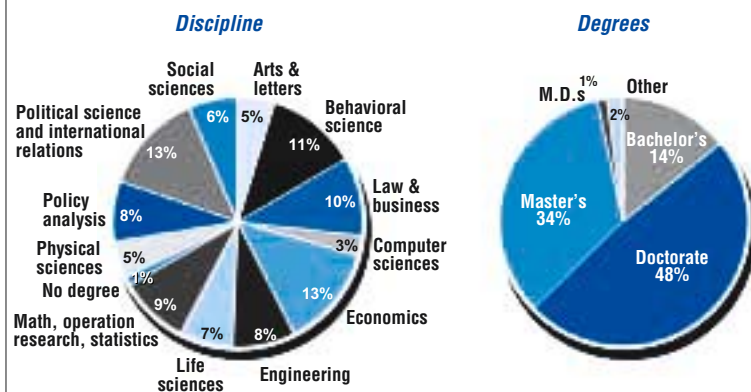
This approach is unique to RAND, one of the nation's premier institutions dedicated to the analysis of public policy. Since its inception in 1948, RAND has developed sophisticated decision-support tools and methods to analyze the nation's most urgent public policy concerns and has delivered sound, objective advice to government decision-makers. RAND has forged long-term relationships with federal research sponsors while maintaining the independence necessary to conduct rigorous, objective analysis.

To this mission, RAND brings unique characteristics. These include its reputation as an objective third party and trusted advisor to both government and business. RAND has a professional staff of over 700 scholars, former decisionmakers, and analysts—plus access to hundreds of outside

experts and consultants when needed. As illustrated in the figure, the RAND staff includes researchers with advanced degrees in engineering, physical sciences, operations research, statistics, economics, computer science, behavioral science, political science, law, business, and other fields. Many senior members of RAND's staff are nationally recognized for their work and expertise.

RAND researchers are located in Santa Monica, California (RAND's corporate headquarters); Washington, D.C.; New York City; Pittsburgh, Pennsylvania; Leiden, the Netherlands; Hamburg, Germany; and Cambridge, England. A core group of S&TPI staff in RAND's Washington Office maintains close contact with OSTP staff and agencies of the Executive Branch. This institute's director meets regularly with the OSTP director and staff, NSF staff, and other high-level personnel to discuss current needs of the Executive Branch.

RAND's Key Resource Is Its 700-Member Professional Research Staff



RAND's professional expertise is multidisciplinary.

What Our Analysis Has Found

The resources available to address the broad range of science and technology issues of importance to the United States are limited. Accordingly, S&TPI focuses on those questions that are of greatest concern to the president of the United States and his senior advisors. Using policy-analytic methods, many developed by RAND—such as modeling, technology forecasting, surveys, financial analysis, bibliometrics, and other tools—the Institute conducts work across a broad range of science and technology policy issue areas. These issues fall into three broad categories: (1) **safety and security** concerns

affecting the American public, (2) **continuing challenges** facing the nation, and (3) **emerging governance issues** that flow from new developments in science and technology. In each of these areas, the Institute has conducted groundbreaking research and continues to seek new methods for enhancing the decisionmaking process.

Safety and Security. The public depends on the government to ensure national security and the safety of infrastructural systems. Safety and security issues are becoming even more pressing as the United States considers responses to its current energy crises, global climate change, and the safety of the national aviation system. Research conducted by S&TPI analysts has influenced investment in energy-efficient technologies for the automobile and housing industries, protection of the information infrastructure, and options for new satellite and space exploration technologies.

- **Security and Critical Infrastructure Protection.** As the Y2K experience illustrated, the rapid spread of information infrastructures raises concerns about networks' vulnerabilities to system failure, enemy sabotage, and criminal misuse. Our work on critical infrastructure protection in both national security and law enforcement contexts has helped OSTP establish priorities and shape the research and development (R&D) budget for infrastructure protection.
- **Space, Satellites, and Aviation.** Budget constraints and a growing private-sector role have transformed the U.S. space enterprise. At the same time, substantial growth in air

traffic and rapid shifts in the aerospace industry have created a range of new policy concerns. These include the tension between safety and capacity in air transportation systems, the growing need for space operations funding and its impact on R&D funding for both exploration and air safety, and the need to use available funding in ways that most effectively benefit the American public. Our work in this area has helped to inform major policy decisions concerning important technologies, such as the Global Positioning System (GPS), which in turn have affected industry and international policy arenas by clarifying the direction of U.S. policy and adding the stability to policy environments that can enable economic growth and international cooperation.

- **Public Safety.** Public safety and the impact of crime have long concerned America. Technology relates to such concerns in two ways: It unfortunately provides new opportunities for criminal activity. It also fosters scientific techniques such as DNA analysis that can ultimately improve the fairness and effectiveness of law enforcement, the courts, and our corrections system. Institute work on new forms of criminal activity in cyberspace have illuminated the potential for such problems as money laundering using cyber technologies and highlighted current limitations in dealing with such problems. In seeking solutions,

S&TPI work on crime-fighting technology has helped shape joint initiatives by the administration and Congress to provide support to local and state law enforcement through the use of advanced technology and scientific techniques.

Continuing Challenges Facing the Nation. One of the most important challenges facing the United States is to maintain a dynamic national innovation system. To enhance the lives of Americans, the system requires an educated workforce, a well-managed health care system, and environmental management that does not overly tax economic growth. These issues present coordination challenges to the federal government as it considers views from disparate communities on key issues such as educational technology; funding medical research, clinical trials, and other aspects of medical innovation; new ways of producing energy; and managing impacts of our economic growth on the environment.

- **Education.** Two developments—the growing importance of scientific education for a technologically literate workforce and the potential for computers to improve student achievement—have brought science and technology issues to the fore in education policy circles. S&TPI research suggests that technology in the classroom can be a powerful tool, but that teaching methods must also be reformed and classrooms reorganized if the United States is to fulfill the promise of emerging technologies.
- **Health.** The transition in health care brought about by the introduction of managed care presents challenges to parts of the health care system that formerly operated under a different set of rules. Medical technology, broadly construed, embraces all innovations in medicine as well as the application of other sciences—such as mathematics, physics, and computation—to therapeutics and diagnostics. Such innovation can change the cost structure of delivering health care for insurance companies, drug providers, researchers, and the patients. Often, concern is expressed that such uses of technology will raise health care costs, but over the long run such innovation has lowered costs, improved quality, or both. Such innovation does demand adaptation and change if its greatest benefits are to be enjoyed by the public. S&TPI has examined this issue from several perspectives and found that (1) a balanced federal role in health care-related R&D is vital and (2) it is prudent to examine the impact of the shift to managed care on our medical innovation system—particularly its consequences for the conduct of clinical trials.
- **Energy and the Environment.** The complexity of issues involved in understanding the impact of the industrialized world on the environment requires an interdisciplinary

approach to problem solving. How should we encourage sustainable growth? How should we monitor the national forests? Can greenhouse gas emissions be successfully reduced? These are all issues to which S&TPI has applied the skills of many disciplines, including economics, technology assessment, chemistry, biology, and social sciences.

Emerging Governance Issues. Challenges that may require more government attention result from rapid advances in technology that press on decisionmakers in ways that threaten to outstrip the response times and capabilities of traditional government structures. Among these challenges is the need to understand the evolving federal role in helping industry operate in a global market and playing this role effectively despite rapid change and the uncertainty that technology-driven change creates. Another challenge is presented by so-called “game-changing” technologies—those that may indelibly change our lives and our society in ways that could call for a strong government role. However, deciding what the appropriate government role is and carrying that role out effectively are exceedingly difficult because of the aforementioned uncertainty associated with technological innovation. Accordingly, S&TPI has identified new challenges posed by rapid technological change in a number of high-impact areas, including international cooperation in research and development, the federal research budget, and the ethical and scientific issues associated with genetic technologies.

- **Stewardship of the U.S. Innovation System in a Global Context.** The transformation of the U.S. economy over the past 20 years has made it clear that innovations based on scientific and technological advances have become a major contributor to our national well-being. The national system that supports this innovation process has emerged as one of our most important national assets. The major actors in this system—the private sector, government agencies and labs, universities, the nonprofit research sector—relate to each other in complex ways that are not easy to describe or to trace through the system. Given the importance of this system to public welfare and the continuing importance of government as both a participant in and a provider of crucial elements of support, it is appropriate to understand what kinds of government actions (or for that matter, inactions) would contribute most to its continued development. There are three areas in which the federal role in the innovation system is most clearly appreciated: managing the federal R&D portfolio; working with the private sector and universities as partners to enable innovation; and working in cooperation with our international partners on science and technology.
- **The Federal Investment in R&D.** This investment is widely seen as the wellspring of the innovations that promote economic growth and improve quality of life. Yet this large federal investment is not managed as a

Accomplishments

2000

- Helped in the transition to a new administration by convening a panel of experts, including several former Science Advisors to the President, to identify key science and technology issues facing the new administration
- Helped form the Washington Science Policy Alliance, a group of science and technology policy organizations
- Provided the analytic basis for an executive order on guidelines and principles for strengthening the partnership between the federal government and research universities
- Published the first-ever overview of state-by-state spending of federal R&D funds
- Provided the analytic support underpinning OSTP's development of the R&D budget for critical infrastructure protection
- Testified before Congress on standards for the future operation of the Internet
- Helped the president's science advisor host the White House conference on national security science and technology (noted by attendees as the first time such a meeting of all federal agencies conducting R&D affecting national security had ever been held)

1999

- Analyzed technical issues for a presidential initiative on aviation safety and security
- Advised the president's National Bioethics Advisory Commission on technical, ethical, and legal issues
- Developed the data for the President's Council of Advisors on Science and Technology (PCAST) report, *Powerful Partnerships*. This report spurred congressional action mandating additional resources.
- Provided the analytic basis for the presidential decision to approve the launch of the radioisotope thermal generators contained on the Cassini mission to Saturn

1998

- Issued the fourth National Critical Technologies Report in a widely distributed RAND publication
- Testified before Congress on U.S. government spending on international R&D with research that was cited in the congressional report, *Unlocking Our Future: Toward a New National Science Policy*
- Testified before Congress on the use of technology in elementary and secondary school education

1997

- Provided the analytic background and framework for the National Science and Technology Council (NSTC) report on children, *Investing in Our Future*
- Published first-ever review of U.S. government spending on international R&D

1996

- Published a report on the global positioning system that underpinned the Presidential Decision Directive enabling commercial access to and use of that resource, which has added an estimated \$8 billion to the U.S. economy

1995

- Advised the NSTC committee developing metrics for science in the wake of the Government Performance and Results Act (GPRA)

1994

- Published first major report, the congressionally requested study of the U.S. machine tools industry

1993

- Began a review of federal sources of information on R&D spending that eventually led to the creation of the RaDiUS data system

coherent whole. S&TPI has helped the federal government better manage these investments by gathering data and providing insights into R&D resource allocation. These have included the first-ever comprehensive database of federal R&D and a first-ever review of R&D spending on a state-by-state basis.

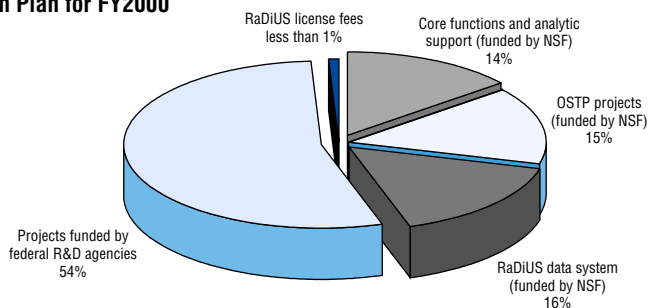
- **Partnerships.** Institute research has been instrumental in helping OSTP and federal agencies develop strategies for partnerships with industry and universities that are designed to exploit the comparative advantages of government, academia, and the private sector.
- **International Cooperation.** Innovation is increasingly the result of international cooperation in science and technology. These shifts challenge the notion of a nationally based science and technology policy because national boundaries have diminishing significance for scientific activities and the results of research are not necessarily exploited at their origin. S&TPI research has helped identify the extent of international R&D funded by the federal government and highlight approaches to ensure that these activities are structured in a way that benefits the United States.

- **Managing Game-Changing Technologies.** Developments in science can also mean new governance challenges to the federal government. Should the government regulate cloning techniques? Does it make sense to tax Internet-based commerce? Will nanotechnology provide breakthroughs that will revolutionize national security? Is the Internet a threat to personal privacy or to children? S&TPI has laid out the possibilities and assessed some of the consequences through reports or workshops conducted at RAND. Each presents options that decision-makers can consider in planning for rapid and surprising developments that may require government consideration.

How We Have Organized This Report

The sections that follow summarize S&TPI's research activities in areas critical to the national welfare that involve science and technology policy issues. These sections correspond to the three areas discussed above: safety and security, continuing challenges, and emerging governance issues. Each section highlights major policy questions, ways in which S&TPI has responded to such questions, major research projects, and how these projects have informed government policy decisions.

Overall Balance of S&TPI Research Plan for FY2000



Many federal agencies invest in S&TPI policy research.

Sponsors and Sources of Funding

When Congress created the S&TPI, it specified that, although the mission of this federally funded research and development center was to support the OSTP, it would be sponsored by the NSF. The congressionally authorized appropriation allocated by NSF for the Institute to conduct core research, support OSTP projects, and maintain the RaDiUS data system in fiscal year 2000 was \$4.2 million.

As shown in the figure above, many other federal agencies invest in policy research at the Institute. Additional projects are funded or co-funded by agencies on a variety of policy issues, often leveraging the resources allocated for support of OSTP. Including this agency funding and revenue from the RaDiUS license fees from nongovernment users, the overall investment in S&TPI research for 2000 was almost \$10 million. While projects may be carried out at the request of the OSTP or federal agencies, the information ultimately benefits the science and technology planning programs of the entire Executive Branch and serves as a vehicle for coordination.

Sponsors of S&TPI research include

National Science Foundation
 Department of Justice
 Department of Defense
 Department of Energy
 National Institutes of Health
 Centers for Disease Control
 Department of Education
 Department of Housing and Urban Development
 NASA
 National Bioethics Advisory Commission
 Office of National Drug Control Policy
 Council on Environmental Quality

The national security of the United States, broadly understood, includes the systems on which Americans depend and that require oversight, investment, and regulation by the federal government. Science and technology are critical components of the national safety and security system. From the creation of the Internet, to maintaining satellite systems, to providing cost-effective energy sources, the Executive Office of the President deals with a complex and interrelated set of issues involving science, technology, and security.

Protecting Critical Infrastructure

Growing U.S. reliance on information networks has raised a range of new policy concerns, including networks' vulnerability to attack or sabotage, their susceptibility to criminal abuse, and the needs for standards setting. OSTP is responsible for oversight of critical infrastructure protection R&D programs, public-private-sector information sharing, and intergovernmental coordination. RAND experts in computer science, electric power generation and distribution, and countering terrorism have helped OSTP meet its oversight responsibilities by

providing analysis on a number of security-related issues.

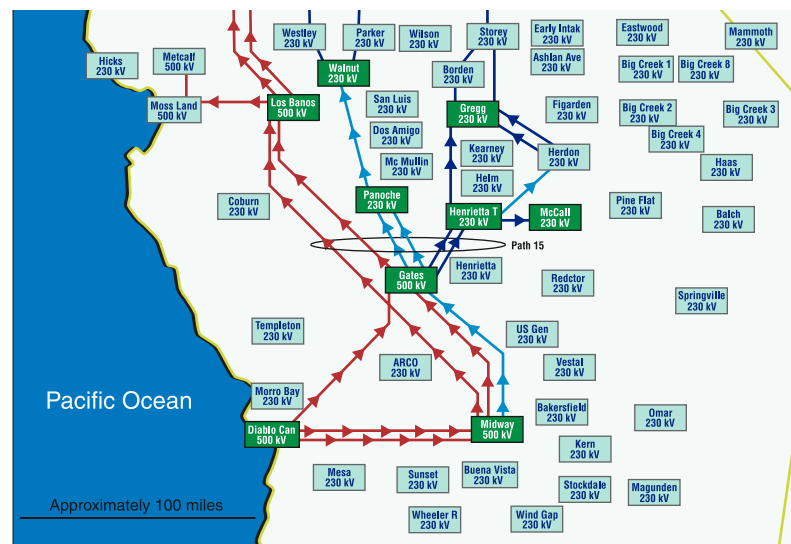
Security of the National Information Infrastructure

The vast and growing information infrastructure underpinning all vital U.S. commercial and government functions raises basic security and system vulnerability considerations. What are the threats? What are the weaknesses? How can it be protected? *The Cyber-Posture of the National Information Infrastructure* examined these issues surrounding the national information infrastructure. Noting that the electric power infrastructure and the telecommunications infrastructure are the foundational systems at risk, the study recommended that these two interdependent systems should be the initial priorities for critical infrastructure protection (CIP). With regard to the information infrastructure, which requires both power and telecommunications to function, the study concluded that the country is not in imminent danger of major cyberspace attacks. Nonetheless, the United States should not be complacent about the possibility of such attacks or view such threats as purely hypothetical. Cyber-attacks are feasible and could have significant consequences. The study also called for a baseline assess-

ment of current vulnerabilities and preparedness in specific sectors. It urged that joint action by the U.S. government and the private sector to devise measures for intelligence, early warning, and data sharing is collectively an early order of business. The report was used by OSTP as an independent adjunct to the blue-ribbon panel review of the nation's critical infrastructure, known as the Marsh Report.

Security Lessons from Y2K. RAND researchers worked closely with OSTP in anticipation of the Y2K “crisis” to provide real-time advice on policies and procedures. RAND then evaluated the lessons learned from the Y2K experience to inform the ongoing task of addressing vulnerabilities in critical infrastructure. The project conducted a series of facilitating workshops for government and private-sector representatives to discuss remediation programs and plans; organizing an ad hoc working group comprised of national experts in CIP; and analyzing in detail the process for allocating budgetary resources to CIP R&D. RAND’s report on these efforts, *Y2K/CIP Lessons Learned Workshop After Action Report*, contributed to the fiscal year 2001 CIP R&D planning process. An additional report, *Y2K and CIP Research and Development: Concepts for Protecting Critical Infrastructure*, provided a conceptual framework for setting R&D priorities for critical infrastructure research during the key formative years of the federal program.

Improving Infrastructure Security and Reliability with New Technologies. S&TPI is developing concepts for supporting the nation’s CIP efforts



Sophisticated simulations of California's electric power grid are being used to assess the potential for HTS technology to increase the robustness of the system. Here the Northern California–Southern California interconnect is being examined to evaluate the potential for HTS technologies to relieve the current “bottleneck” and provide added robustness and redundancy.

through the use of new and innovative technologies. One of the most promising opportunities involves technology based on the mid-1980s discovery of high-temperature superconductivity (HTS). Since 1988, the Department of Energy has pursued a government/industry/university team approach to the development of commercially usable technologies based on this phenomenon, through its Superconductivity Program for Electric Systems. The program has already achieved record performance for wire current-carrying capability. Advanced HTS-based equipment such as power cables, transformers, motors, fault current limiters, current controllers, and electricity storage devices have now reached the demonstration stage. With the participation of equipment manufacturers, national laboratories, universities, and electric utilities, the program seeks to improve the price-performance of such HTS equipment to foster economic incentives for the private sector to replace existing infrastructure. Because this equipment is typically smaller,

more fault-tolerant, and safer than conventional equipment, it may be possible to reconfigure the electric power infrastructure so that it is more reliable and resistant to attack.

A RAND study has found that HTS-based electrical power equipment has technical characteristics that could improve public utility operation and—if incorporated early enough in utility planning—could enhance the reliability and security of U.S. power generation, transmission, and distribution infrastructure. This research is also providing a detailed analysis of ways to overcome commercial and technical barriers to early market entry of HTS technologies, particularly those that have the potential to improve the robustness of our infrastructure to natural and terrorist-based risks.

S&TPI has also begun a project supporting the Center for Disease Control/National Institute for Occupational Safety and Health in examining options for the use of advanced technologies in personal protective equipment for “first responders” to terrorist threats, such as police, firefighters, and emergency medical personnel.

Related Publications

Concepts for Enhancing Critical Infrastructure Protection: Relating Y2K to CIP Research and Development. David Mussington. 2001. MR-1259.

The Cyber-Posture of the National Information Infrastructure. Willis H. Ware. 1998. MR-976-OSTP.

Scaffolding the New Web: Standards and Standards Policy for the Digital Economy. Martin Libicki, James Schneider, David R. Frelinger, and Anna Slomovic. 2000. MR-1215-OSTP.

Securing the U.S. Defense Information Infrastructure: A Proposed Approach. Robert H. Anderson, Phillip M. Feldman, Scott Gerwehr, Brian Houghton, Richard Mesic, John D. Pinder, Jeff Rothenberg, and James Chiesa. 1999. MR-993-OSD/NSA/DARPA.

Standards and the National Information Infrastructure: Implications for Open Systems Standards in Manufacturing. Caroline S. Wagner, Carl F. Cargill, and Anna Slomovic. 1994. P-7882.

Informing the Public

Public libraries are often challenged by limited budgets. The Public Library Association and the American Association of School Libraries annually publish a guide for the more than 15,000 libraries they serve to help librarians choose the best scholarship from the academic and analytic community. Despite its small size, S&TPI contributes significantly to the public education and understanding. Two of the five RAND reports recommended in the 2001 edition of University Press Books Selected for Public and Secondary School Libraries were S&TPI products:

Discovery and Innovation: Federal Research and Development Activities in the Fifty States, District of Columbia, and Puerto Rico by Donna Fossum, Lawrence S. Painter, Valerie Williams, Allison Yezril, Elaine Newton, and David Trinkle (MR-1194).

Scaffolding the New Web: Standards and Standards Policy for the Digital Economy by Martin Libicki, James Schneider, David R. Frelinger, and Anna Slomovic (MR-1215).

Space, Satellites, and Aviation

Budget constraints and a growing private-sector role have transformed the U.S. space enterprise. At the same time, substantial growth in air traffic and rapid shifts in the aerospace industry have created a range of new policy concerns. These include

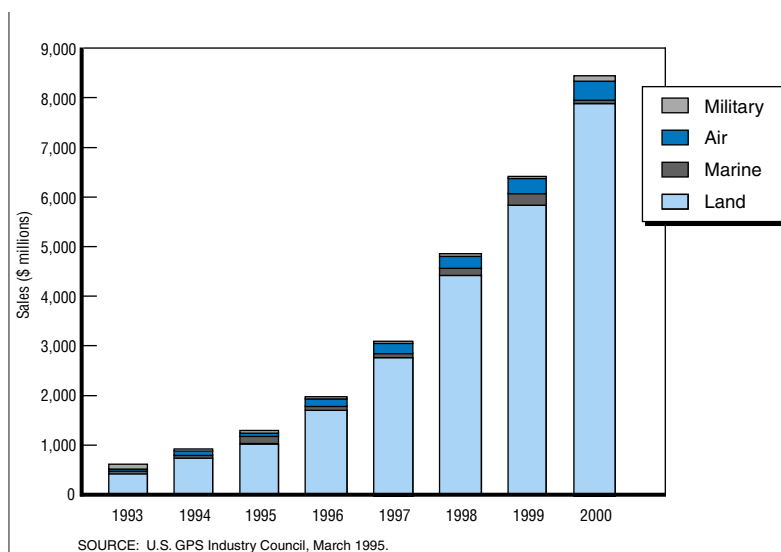
- the growing need for space operations funding and its impact on funding for both exploration and air safety R&D;
- the tension between safety and capacity in air transportation system; and
- the need to use available funding and programs in ways that most effectively benefit the American public.

These new concerns suggest that it is increasingly important to use existing programs in creative ways to benefit the country, to find new and effective ways to use the resources that are available to attack key problems such as the pressure on the air transportation system, and to choose future policies and programs as carefully as possible. In addition to supporting OSTP, particularly in its role on U.S. international negotiations teams, our work in this area has included direct support for NASA and the Federal Aviation Administration. The issues addressed in these analyses include the use of market mechanisms to more effectively conduct agency missions and ways to improve the air transportation system.

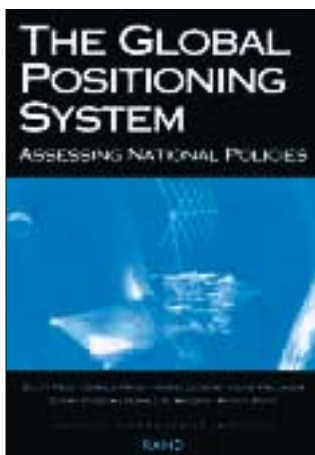
Using Existing Programs to Enhance Benefits for the United States. Science and technology policy matters are often concerned with fiscal decisions—how much the federal government should

invest in R&D and how such funds should be allocated. But policy decisions also rely on other powers of government, particularly agenda setting and leadership: Simply clarifying the direction in which the United States will proceed can enable industry in ways that can have a powerful impact on our security, economy, and quality of life. The presidential decision associated with the Global Positioning System (GPS) exemplifies this impact.

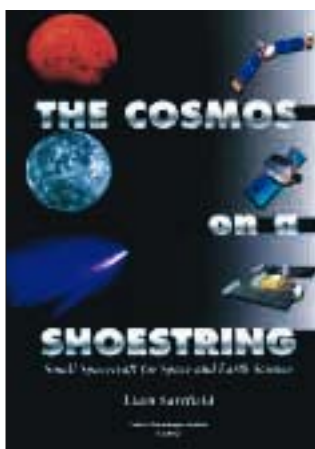
GPS is a set of orbiting satellites that broadcast precise time signals that can be used to aid position location, navigation, and timing worldwide. It was originally deployed by the United States to aid military navigation and position location. Over the past decade, however, GPS has evolved beyond its military origins. It is now an



In the mid-1990s, industry experts predicted rapid growth of GPS-related commerce through 2000. Actual revenues came in very close to these projections.



- Assesses alternative policy regimes and their likely economic, security, and legal implications
- Makes policy recommendations intended to balance military, commercial, and international concerns



- Reviews the growing role that small spacecraft play in the U.S. civil space program
- Examines spacecraft development trends
- Highlights new strategies for reducing cost and improving performance

information resource supporting a wide range of civilian, scientific, and commercial functions, from air traffic control to the Internet. The evolution of GPS into an information system with a substantial international user community has raised complex policy questions for U.S. decisionmakers:

- **Dual Use:** How can GPS policy balance national security and commercial interests most effectively?
- **Governance and Funding:** How should GPS and associated augmentations be governed and funded in the future? With respect to funding, should the U.S. government continue to foot the bill for GPS or collect fees from users?
- **Foreign Policy:** How should the United States address foreign concerns about access to GPS signals and the maintenance of a stable policy environment?

S&TPI's study of these critical issues concluded that GPS enables unique military, commercial, and civil capabilities. The United States has an important opportunity to shape the direction of GPS applications and mitigate the risks of this new technology. The project team recommended that the government articulate such a directive to provide a framework for the various stakeholders—military, commercial, and international. This framework needs to reassure all users that GPS will continue to operate in a stable, reliable manner and provide civilian signals free of direct charges.

Following the study, a Presidential Decision Directive on GPS was issued in 1996 that adopted the principal RAND recommendations. The direc-

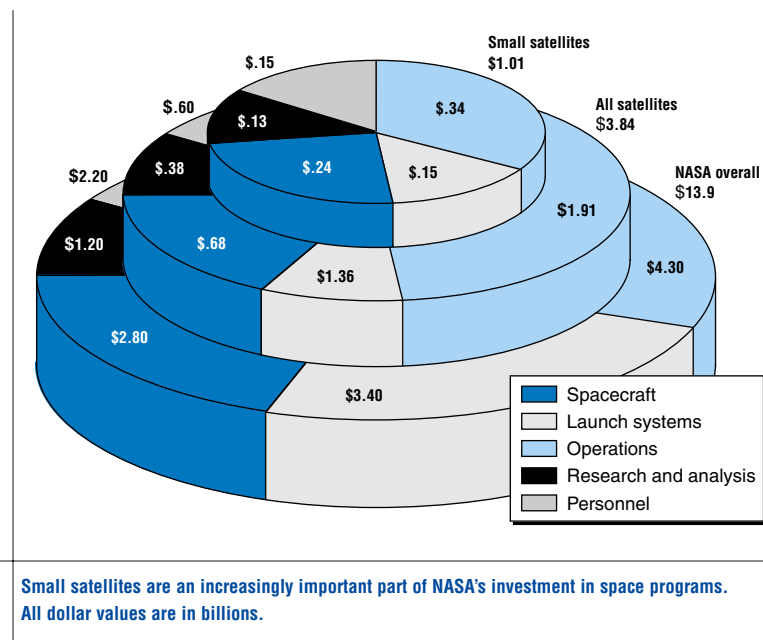
tive set a stable framework for commercial activities using the system, allowing investors and entrepreneurs to confidently undertake business initiatives. The innovation that resulted added \$10 billion to the U.S. economy by the year 2000. That year, the president implemented another recommendation from the study—elimination of the accuracy degradation imposed on civil users. With the flip of a switch, all the GPS receivers in the hands of businesses, private citizens, and other civil users became ten times more accurate.

Using Market Mechanisms and Better Project Management Concepts. The continued demands of space operations put pressure on remaining resources for space exploration, the conduct of scientific missions, and air transport system research. S&TPI has supported both OSTP and NASA in examining ways to best use the resources available for these missions. These efforts have focused on using private-sector and market mechanisms to maximize existing resources for accomplishing government missions, and using better project management strategies to enable more effective space systems development.

Two recent reports—*The Earth Below: Purchasing Science Data and the Role of Public-Private Partnerships* and *Data Policy Issues and Barriers to Using Commercial Resources for Mission to Planet Earth*—explore options for increasing NASA's use of commercial remote sensing systems to make better use of available resources by using new and creative ways to accomplish research missions. This can potentially save the government the costs of developing and deploying new remote sensing systems.

In examining more effective strategies for space system project management, S&TPI's work has focused on cost, risk, and time to deployment. One-quarter of NASA's current investment in space and earth science is spent on small programs, an amount certain to increase as larger programs, now under development, conclude. Within the Department of Defense, the Air Force, the Navy, and the National Reconnaissance Office are exploring ways to shift assets to smaller platforms that can be deployed more rapidly at lower cost. As small spacecraft play a more central role in national space policy, it is important that decisionmakers understand the dynamics of smaller programs and maintain realistic expectations of their potentials. The report *The Cosmos on a Shoestring: Small Spacecraft for Space and Earth Science* provides a comprehensive evaluation of the potential for using small spacecraft to continue the U.S. legacy of space exploration by managing cost, risk, and time to deployment.

Shaping New Space and Aviation Policies and Programs to Benefit the Public. This long-term, direct support activity analyzes issues of interest to OSTP in conjunction with space-related programs, technologies, and national policies. Tasks are requested by OSTP on an as-needed basis and may require diverse technical skills. Much of the work calls for direct analytic assistance rather than producing a major report on one specific issue. The project examines federal R&D plans, the conduct of government-industry partnerships, and ongoing civil and mili-



tary space programs. Efforts include analyses of funding options for government space activities and support for international consultations with Japan, the European Commission, and Russia on issues pertaining to the GPS and space technology-related trade. The project team conducted the risk analysis of the plutonium-based radioisotope thermal generator that formed the basis for the presidential approval that was required by Congress before the Cassini mission to Saturn could be launched. Additionally,

during the 1998 and 1999 World Radio-Electronic Conferences, the U.S. negotiating team used S&TPI project analysis to preclude an initiative by foreign competitors to allocate frequency bands to commercial interests, which could have disrupted the national security and public safety uses of the system.

Related Publications

The Cosmos on a Shoestring: Small Spacecraft for Space and Earth Science. Liam Sarsfield. 1998. MR-864-OSTP.

Data Policy Issues and Barriers to Using Commercial Resources for Mission to Planet Earth. Scott Pace, Brant Sponberg, and Molly Macauley. 1999. DB-247-NASA/OSTP.

The Earth Below: Purchasing Science Data and the Role of Public-Private Partnerships. Scott Pace, David Frelinger, Beth Lachman, Arthur Brooks, and Mark Gabriele. 2000. DB-316-NASA/OSTP.

The Global Positioning System: Assessing National Policies. Scott Pace et al. 1995. MR-614-OSTP.

GPS-Aided Guidance for Ballistic Missile Applications: An Assessment. Gerald P. Frost and Irving Lachow. 1996. RP-474-1.

The Regulation of Commercial Remote Sensing Systems (congressional testimony). Scott Pace. 1994. CT-112.

Remote Sensing Operational Capabilities: Final Report. David Frelinger and Mark Gabriele. 1999. MR-1172.0-OSTP.

Public Safety

Crime in Cyberspace. The growth of the Internet has provided new opportunities for international money laundering and other forms of financial fraud and abuse, posing an entirely new range of challenges for law enforcement. At the request of the Financial Crimes Environment Network of the U.S. Department of the Treasury, RAND conducted a strategic decision-making exercise to explore the potential for criminal abuse of cyberpayment systems. The resulting report, *Cyberpayments and Money Laundering: Problems and Promise*, concluded that cyberpayment systems could undermine current law enforcement strategies nationally and internationally unless preventive measures are instituted. A follow-up report, *Exploring Money Laundering Vulnerabilities Through Emerging Cyberspace Technologies: A Caribbean-Based Exercise*, outlined first steps toward international cooperation to prevent crimes related to cyberpayment systems. A Spanish translation of the report is also available from RAND.

Crime-Fighting Technologies. State and local governments typically spend 95 percent of their law enforcement budgets on personnel, leaving little funding for the development, purchase, and deployment of updated technologies despite their significant enhancement of law enforcement operations. Drawing on expertise from RAND's Criminal Justice program, S&TPI staff examined the possibilities for federal assistance in helping state and local law

enforcement adopt up-to-date crime-fighting technologies.

In *Needs and Prospects for Crime-Fighting Technology: The Federal Role in Assisting State and Local Law Enforcement*, S&TPI staff recommended ways to make the optimal use of federal funding to help state and local agencies upgrade capabilities and share capabilities across jurisdictions. The analysis served as the blueprint for a White House initiative to increase funding for crime-fighting technology support to state and local governments and was cited by both the attorney general and members of Congress during a bipartisan conference on the issue held at the White House Conference Center in July 2000.

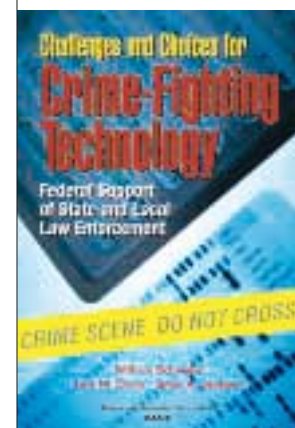
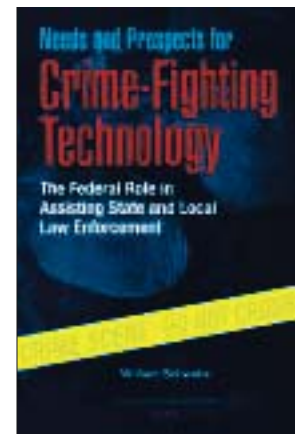
In a second project in the crime-fighting series, S&TPI staff surveyed nearly 500 local and state law enforcement agencies and forensic laboratories to determine their perspective on their needs for and the effectiveness of new technologies. The report identified technologies currently unavailable to many police departments, examined barriers faced by law enforcement organizations to adopting new technology, and described potential federal responses to these problems. Forensic laboratories were identified as particularly overburdened but seriously constrained by resource and technology shortages. In addition, training—both to use available technologies and the development of technology for training—was highlighted as a priority in

police departments and forensic laboratories. The RAND study team has detailed its findings in *Challenges and Choices for Crime-Fighting Technology: Federal Support of State and Local Law Enforcement*.

To follow up these efforts, S&TPI is currently conducting analysis to support the attorney general's science advisor in an evaluation of the Department of Justice's requirements for its worldwide telecommunications system.

Coordinating and Assessing the Anti-Drug Budget. The White House Office of National Drug Control Policy (ONDCP) coordinates the nation's anti-drug efforts and the drug enforcement budgets of the multiple federal agencies that are involved. Because the national counterdrug strategy relies heavily on R&D to develop and use new scientific information and advanced technology, and because of S&TPI's experience in evaluating R&D investments, ONDCP requested help from the Institute in assessing the agencies' budgeting efforts and methodologies.

The study examined the anti-drug budgets of the nine federal agencies that spend the most on drug control efforts (the FBI; Coast Guard; Departments of Defense, Education, and Veterans Affairs; Bureau of Prisons; Substance Abuse and Mental Health Services Administration; Immigration and Naturalization Service; and



- Assess difficulties that state and local law enforcement agencies face in obtaining and deploying updated crime-fighting technologies
- Recommend ways to optimize federal assistance, so that the potential for state and local law enforcement officials to use new crime-fighting technologies is maximized with the available federal funding
- Identify opportunities for improving the efficiency and effectiveness of law enforcement through the use of technology
- Highlight differences in technologies that influence their deployment by law enforcement organizations
- Emphasize the importance of less-recognized technology needs such as command and control technology, administration and accounting systems, and training equipment for local police forces

Customs). Some methodologies were appropriate and provided reasonable estimates. Others, however, had serious deficiencies: Some were based on unsound premises or guesswork, while others proceeded from reasonable assumptions but were poorly implemented. The net effect of these inconsistencies is uncertain, but it is likely that several agencies overestimate their anti-drug budgets. The study's findings appear in *Improving Anti-Drug Budgeting*. Based on RAND's recommendations, the ONDCP has made some improvements in their budget methodologies, as well as in their presentation. But more still needs to be done before the American people and Congress can have confidence in official statements of anti-drug spending.

Related Publications

Challenges and Choices for Crime-Fighting Technology: Federal Support of State and Local Law Enforcement. William L. Schwabe, Lois M. Davis, and Brian A. Jackson. 2001. MR-1349-OSTP-NIJ.

Cyberpayments and Money Laundering: Problems and Promise. Roger C. Molander, David A. Mussington, and Peter A. Wilson. 1998. MR-965-OSTP/FinCEN.

Explorando Las Vulnerabilidades Del Lavado Del Dinero Por Medio De Las Tecnologías Emergentes Del Ciberespacio: Un Ejercicio De Base Caribeno. David A. Mussington, Peter A. Wilson, and Roger C. Molander. 1998. MR-1005/1-OSTP/FinCEN.

Exploring Money Laundering Vulnerabilities Through Emerging Cyberspace Technologies: A Caribbean-Based Exercise. David A. Mussington, Peter A. Wilson, and Roger C. Molander. 1998. MR-1005-OSTP/FinCEN.

Improving Anti-Drug Budgeting. Patrick Murphy, Lynn E. Davis, Timothy Liston, David Thaler, and Kathi Webb. 2000. MR-1262-ONDCP/NSF.

Needs and Prospects for Crime-Fighting Technology: The Federal Role in Assisting State and Local Law Enforcement. William Schwabe. 1999. MR-1101-OSTP.

America's economic growth and quality of life depend upon an educated workforce, a cost-effective health care system, and a sustainable environment. The Executive Office of the President has broad oversight of the features of the national innovation system, including R&D, education, and funding for university research. In addition to analysis detailing the complex interactions that create the nation's innovation system as a whole, S&TPI has provided key inputs to Executive Branch decisions on educational technology, the health care system, and the environment.

Education

Concerns about maintaining a scientifically literate workforce for the emerging "high-tech" economy, coupled with high hopes for the educational potential of computers and the Internet, have catapulted science and technology issues into prominence in the education debate since the late 1990s. Drawing on RAND's resident expertise in both education and information technology, the S&TPI studied several aspects of these issues for the NSF and the Department of Education.

Involving Universities in K–12 Education Reform. Not since the Sputnik "crisis" of the 1950s has so much public attention focused on the need to improve science education in the United States. However, current circumstances differ from the earlier period in fundamental ways. The reaction to Sputnik was driven by national security concerns growing out of the Cold War with the Soviet Union. Underlying the crisis was the fear that eroding scientific preeminence jeopardized U.S. security. Response to the crisis focused on producing more scientific specialists and restoring U.S. ascendance in key scientific fields. By contrast, the issue since the late '90s has not been the need for more scientific specialists but rather for a better-trained, scientifically literate workforce and citizenry. The main concerns have centered on equity and economic competitiveness rather than national security.

One approach to reforming science education in the United States has paired university science students at the graduate and undergraduate levels with K–12 teachers. This approach has not been free of controversy, however. Some have questioned the effectiveness

of these partnerships and raised doubts about whether universities should become involved in K–12 education. Because of NSF’s interest in developing programs that use some form of this approach, NSF asked RAND to study the range of current programs that connect science graduate and undergraduate students to K–12 classrooms. The goal of this research was to identify the challenges of creating such programs, their impacts, and successful strategies for implementation. RAND researchers gathered information from site visit interviews to eight outreach programs. The report *Merging University Students into K–12 Science Education Reform* concluded that these programs can have significant impacts on all of the participants.

- For K–12 teachers, the outreach programs helped to reduce their sense of isolation, increase their confidence in teaching science, give them additional teaching tools, and create more time for science instruction.

- For K–12 students, the main impacts (as reported by the teachers) were greater enthusiasm about science, increased interest in scientists and science careers, and enhanced awareness about universities and educational opportunities.
- For university students, the main impacts were improved communication skills, deeper understanding of scientific concepts, and broader awareness of the impact of education.

The main challenges to implementing and sustaining the programs involved building support within the university culture.

The study will help to inform larger-scale assessments of NSF’s GK–12 program, which pairs universities with K–12 schools in a variety of settings.

Technology in the Classroom: Opportunities and Costs. Computer-based technologies now pervade the American workplace and home; schools are not far behind. In 1995, primary and secondary schools possessed a computer for every nine students, roughly a 13-fold increase since 1983. Spending on computer-based technologies has likewise jumped: Schools and districts were spending about \$3 billion nationwide by the mid-1990s. Is the investment paying off? An S&TPI study of computer use in American schools suggests that educational technology has begun to improve student performance and holds the potential for enabling far greater improvement.

Overall, the research gave schools mixed marks on their use of information technology.

Annualized Expenditures of Educational Technology in Public K–12 Schools for Several Levels of Investment

	Technology Expenditures Per Student	Annual Expenditures for Education Technology (billions of dollars)	Percentage of Current K–12 Expenditures
Current	\$70	3.1	1.2
Moderate	\$180	8.0	3.2
High	\$450	19.9	8.0

NOTE: For public K–12 schools with 1994–95 fall enrollment of 44.2 million students and total expenditures of \$6,300 per student.

Creating technology-rich environments in American schools would carry a substantial price tag.

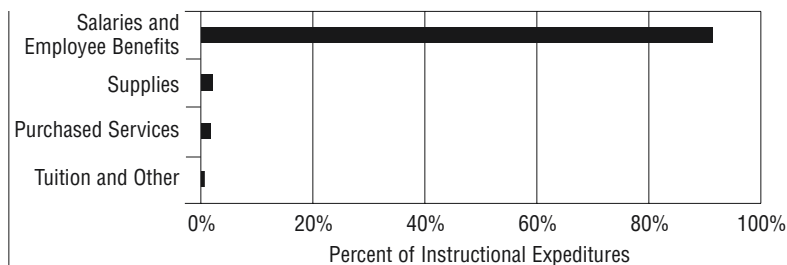
Despite substantial increases in spending on computer-based technology, most schools still make limited use of computers and have little access to other technologies.

Costs continue to limit widespread use. Although the total cost of computer technology represents a small fraction of overall education budgets, this spending often comes at the expense of other needed supplies and materials and is therefore very restricted.

Costs aside, there are two other barriers to large-scale adoption of educational technology: insufficient training to enable teachers to exploit the potential of the new technology and a dearth of quality content software.

Researchers conducted case studies of five “technology-rich” schools. They also estimated the costs of creating such schools and examined the prospects of incorporating technologies into schools more extensively. In addition, educators, industry experts, and policy insiders were invited to exchange views at a series of workshops. To get a broader picture, researchers also interviewed a range of experts and examined the growing body of scholarship on the subject of technology in education.

The findings, reported in *Fostering the Use of Educational Technology: Elements of a National Strategy*, showed that educational technology has indeed begun to help improve student performance and holds the potential for enabling far greater gains. However, schools to date have tended to adopt technological improvements piecemeal, thereby limiting their value. The research emphasized that educational technology must be infused into schools as part of a broader reform

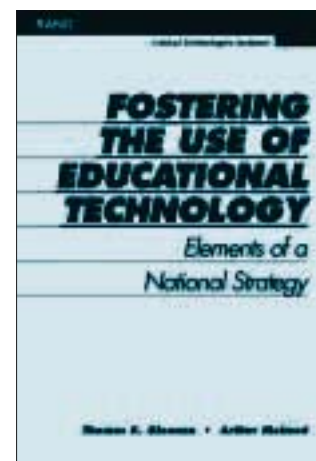


Given the high proportion of school spending devoted to salaries and benefits, creating technology-rich schools may require some reallocation of resources (estimates are for 1991-92).

agenda, which should pay careful attention to the lessons from the successful early experience of a few innovative schools. The report has helped inform Department of Education and OSTP decisionmaking in this area. The lead investigator was asked to present the results to Congress.

Based on the results of this first evaluation of educational technologies, the Department of Education and OSTP asked S&TPI to conduct two follow-on studies. The first report, *The Cost of School-Based Educational Technology Programs*, chronicled eight detailed case studies of schools that use computer technologies in classroom instruction to estimate costs of establishing technology programs. The second report, *Evaluating Challenge Grants for Technology in Education: A Sourcebook*, provided a model for evaluating federal matching grants to schools to establish or bolster use of technologies in the classroom.

Donating Surplus Federal Computers to Public Schools. Federal agencies were required under an executive order to donate obsolete or surplus computers to public schools. However, because the mandate included no funding or



- Examines effects of information technology in K-12 schools
- Finds that some model schools have used adopted technology effectively but many more have not
- Concludes that properly implemented educational technology programs can aid school reform, but costs will be substantial
- Is widely cited in educational technology research literature

staffing for carrying out the mission, there were concerns that the mandate was having little effect. S&TPI was asked to study the issue in support of a Senate request to OSTP for an evaluation of the program. RAND researchers quantified the potential supply of surplus government computers and compared this supply with school needs. The researchers also compiled data and information about similar, private-sector programs. Based on these data, RAND identified and analyzed a range of possible options for improving the government programs. Finally, the RAND team identified barriers to the efficient implementation of the federal program. OSTP used the resulting RAND report, *Surplus Federal*

Computers for Schools, to respond to the Senate call for an evaluation and to improve the effectiveness of the federal surplus computer program.

The Institute's most recent work on education helps the Department of Education and other interested federal agencies design an effective educational research program to answer long-standing questions about how children learn reading and mathematics and how this knowledge can be put to practical use in the classroom by teachers. A Web site (www.rand.org/multi/achievementforall) is available for public, educator, and researcher comment and discussion.

Related Publications

The Cost of School-Based Educational Technology Programs. Brent Keltner and Randy L. Ross. 1996. MR-634-OSTP/ED.

Elements of a National Strategy to Foster Effective Use of Technology in Elementary and Secondary Education. Thomas K. Glennan. 1998. CT-145.

Evaluating Challenge Grants for Technology in Education: A Sourcebook. Susan Bodilly and Karen J. Mitchell. 1997. MR-839-ED.

Fostering the Use of Educational Technology: Elements of a National Strategy. Thomas K. Glennan and Arthur Melmed. 1996. MR-682-OSTP/ED.

In Pursuit of Prestige: Strategy and Competition in U.S. Higher Education. Dominic J. Brewer, Susan M. Gates and Charles A. Goldman. 2001. New Brunswick, N.J.: Transaction Press.

The Ph.D. Factory: Training and Employment of Science and Engineering Doctorates in the United States. Charles A. Goldman and William F. Massy. 2001. Boston, Mass.: Anker Publishing Company.

Surplus Federal Computers for Schools: An Assessment of the Early Implementation of E.O. 12999. Thomas K. Glennan, Jr., Walter S. Baer, Susanna Purnell, Gwendolyn Farnsworth, and Gina Schuyler. 1997. MR-871-OSTP.

Will the Internet Transform Higher Education? Walter S. Baer. 1998. RP-685.

S&TPI Web Resources



Science and Technology Policy Institute

www.rand.org/scitech/stpi

The main Web site contains an introduction to the Institute, including the legislation authorizing it and its congressional charter. The site also contains brief descriptions of ongoing projects and an historical record of completed work. There is also a catalog of the Institute's reports, which are provided on-line in full text.



RaDiUS Data System

www.rand.org/services/radius

RaDiUS, which stands for Research and Development in the United States, is the only comprehensive database on R&D funded by the federal government. RaDiUS is the first database that tracks in virtually real-time the R&D activities and resources of the government.



Our Future, Our Environment

www.rand.org/scitech/stpi/ourfuture

This Web site was created for the White House Council on Environmental Quality. This is a multimedia "e-zine" with articles, video clips, and audio clips about our environmental future, our options, and our opportunities.



Achievement for All

www.rand.org/multi/achievementforall

Created for the Department of Education's Office of Education Research and Improvement, this Web site's goal is to bring together researchers, teachers, developers, and policymakers to create, debate, and apply research findings and the wisdom of practitioners to solving education problems in reading and mathematics.



Renewing the Federal Government–University Research Partnership for the Twenty-First Century

www.ostp.gov/html/rand/index.htm

The Assistant to the President for Science and Technology issued a Presidential Review Directive in September 1996, asking the National Science and Technology Council (NSTC) to review the government–university partnership in research and associated educational activities, and to recommend ways to strengthen it. This Web site was created for OSTP and NSTC and contains background information on the issue as well as the final report submitted to the president.

Health

Costs of Clinical Cancer Trials. Many health insurance providers are restricting payments for participation in studies of new cancer treatment protocols because of concerns that participation in such trials increases patient care costs. Such restrictions by insurance providers threaten to undermine the effectiveness of clinical trials and the ability of patients to participate. Yet, data on costs of clinical trials have never been gathered. For this project, RAND is tracking treatment costs for 750 patients enrolled in clinical trials being funded in part by the National Institutes of Health at 55 randomly selected institutions across the country. Costs for the 750 participants are being compared with costs for 750 “control”

patients enrolled in cancer treatment programs that are not part of clinical trials. Because this project involves human subjects, the research methodology had to be carefully designed to protect the participants. The method was peer reviewed and documented in detail in the report *The Cost of Cancer Treatment Study's Design and Methods*. Public comments are also being incorporated into the research. A Web site (www.costofcancer.org) provides a mechanism for public input. The final results of this project will provide quantitative cost comparisons to inform the debates about the relative costs of clinical trials for cancer treatment.

Creating a National Resource for the Research Community. S&TPI provided OSTP and the National Bioethics Advisory Commission (NBAC) with a comprehensive assessment of the number of human tissue samples held by hundreds of institutions across the United States and their value to the research community. It found that more than 303 million tissue specimens—some more than 100 years old—are stored in various biomedical institutions across the country. They found that stored tissues have played a critical role in understanding and treatment of diseases such as cancer, AIDS, and heart disease. Prior to RAND's work, no comprehensive information was available on the research uses, types, sources, and locations of these tissues. This research and the accompanying RAND analysis pro-



RAND researchers studying cancer-treatment protocols

vided the basis for NBAC's assessment of whether use of such tissues should be allowed in research. Following on the work for NBAC, RAND researchers compiled the first comprehensive catalog of stored human tissues and published a "virtual library" with up-to-date information on stored tissues to make these resources more easily accessible to the research community. The RAND report, *Handbook of Human Tissue Sources: A National Resource of Human Tissue Samples*, is now a reference for researchers studying genetics, cancer, immunology, physiology, and cell biology.

Managed Care and Medical Innovation. S&TPI also has advised OSTP and the National Institutes of Health on issues related to managed health care and control of medical costs. Drawing on the expertise available in RAND Health, S&TPI examined how managed care organizations assess new medical drugs, devices, and procedures to determine how much of the costs of these new medical technologies will be covered. The report, *Health Care in Transition: Technology Assessment in the Private Sector*, quantified the demand for assessments of new medical technologies in managed care organizations, documented how these new technologies are assessed, and analyzed how managed care organizations use the results to make decisions. The study concluded that managed care organizations are increasingly using technical assessments to control the costs of use of new medical technologies. A follow-on report by RAND Health, *Managed*

Care and the Evaluation and Adoption of Emerging Medical Technologies, provides an update and expansion of this analysis in light of the rapid changes taking place in the nation's health care system.



- Provides the first complete national catalog of stored human tissues, which play a critical role in the understanding and treatment of many diseases
- Opens information on human tissues to the biomedical research community
- Provides the basis for NBAC recommendations to the president

Related Publications

Biomaterials Availability: Potential Effects on Medical Innovation and Health Care. Science and Technology Policy Institute. 2000. IP-194.

Cloning Human Beings: Recent Scientific and Policy Developments. Elisa Eiseman. 1999. MR-1099.0-NBAC.

The Cost of Cancer Treatment Study's Design and Methods. Dana P. Goldman et al. 2000. MR-1169-NCI/NIH/OSTP.

Handbook of Human Tissue Sources: A National Resource of Human Tissue Samples. 1999. Elisa Eiseman and Susanne B. Haga. MR-954-OSTP.

Health Care in Transition: Technology Assessment in the Private Sector. Richard A. Rettig. 1997. MR-754-DHHS/ASPE/AHCPR.

Managed Care and the Evaluation and Adoption of Emerging Medical Technologies. Steven Garber, M. Susan Ridgely, Roger S. Taylor, and Robin Meili. 2000. MR-1195-HIMA.

Energy and the Environment

Strategic Planning for Energy Productivity. A recent project assisted the director of the Department of Energy's Energy Efficiency and Renewable Energy program with strategic planning of the program's research agenda for the next 25–50 years. As part of the project, RAND organized a series of activities to examine issues—ranging from systems approaches for optimizing energy use to the effects of information technology on energy use—that might affect future energy use and supply. The project included a survey of top strategic thinkers and government decisionmakers and a workshop involving leading energy experts using the Delphi technique developed at RAND for strategic defense analysis. RAND then analyzed the results of these activities to suggest new directions for the Department of Energy's research agenda, which are discussed in a two-volume report entitled *E-Vision 2000: Key Issues That Will Shape Our Energy Future*. A key concept to emerge from the work suggests that a program focus on energy productivity—to lower the amount of energy used to produce our gross domestic product—would serve the dual purpose of encouraging economic growth while lessening the detrimental impact on the environment (e.g., the production of greenhouse gasses or the emissions of pollutants).

Residential Energy Consumption.

Another project, also for the Department of Energy, assessed whether existing standards for energy-efficient home appliances are biased in favor of one type of energy source over another. For example, critics have suggested that

current policies favor electric water heaters over natural gas units because of errors and unfounded assumptions in the processes used to measure energy consumption. RAND surveyed data from the states to investigate the possibility of such a bias. The resulting report, *Measures of Residential Energy Consumption and Their Relationships to DOE Policy*, showed that current policies have not created a statistically significant difference in markets for appliances using different energy sources.

In two other reports—*Information Technology in the Home: Barriers, Opportunities, and Research Directions* and *The Role of Information Technology in Housing Design and Construction*—Institute researchers took a systems-analysis approach to investigate the ways information technology can be used to enhance construction and use of America's homes to lower both costs and energy use. The research supported the Partnership for Advancing Technology in Housing (PATH), which was established to optimize both government- and private-sector investments in new housing technology. As part of this work, RAND researchers assisted PATH, the Department of Housing and Urban Development, the Department of Energy, and their contractors in developing a road map to guide future investments by applying a decision-support tool to prioritize R&D opportunities in terms of payback per dollar invested.

Enabling Balanced Community

Development. RAND researchers have provided analysis of the effects of alternative, nonregulatory incentives for



- Responds to concerns that existing energy efficiency policies for home appliances are biased in favor of electric units over natural gas units
- Demonstrates through a statistical analysis of data from the states that existing policies cause no such bias

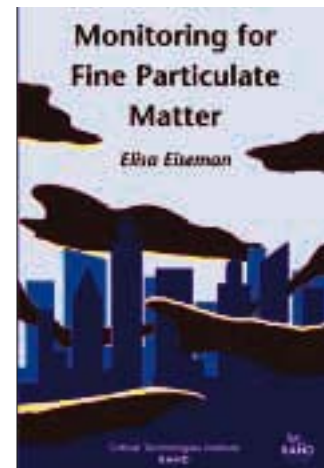
decreasing the impacts of human activities on the environment. *Linking Sustainable Community Activities to Pollution Prevention: A Sourcebook* examined innovative community-based programs for encouraging pollution prevention. The report found that hundreds of U.S. communities have “sustainable community” programs that involve looking comprehensively at economic, social, and environmental concerns and building consensus about how to address those concerns. The report concluded that those interested in pollution prevention activities can use such community-based programs as a basis for their own pollution prevention efforts.

Monitoring the Environment and Ecosystem Management. RAND assessed the adequacy of the Environmental Protection Agency’s new reference method for monitoring for fine particulate material in air. Such monitoring is required to comply with National Ambient Air Quality Standards. As reported in *Monitoring for Fine Particulate Matter*, RAND found that the reference method has significant limitations but that no existing technologies can overcome all of these.

New technologies can help joint government efforts to protect and preserve fragile ecosystems. Recent S&TPI work has examined the capabilities and limitations of satellite and other remote sensing systems to monitor ecosystems. The findings from the overview study are published in *Remote Sensing Operational Capabilities: Final Report* and are included on a CD-ROM that, as shown in the figure, illustrates the dynamics of satellite orbital mechanics and their

effect on the frequency of the coverage provided by remote sensing systems. In a complementary report, *Remote Sensing and Forest Monitoring: A Survey of Accomplishments and Opportunities for the Future*, the research team provides a compendium of ideas for enhancing effectiveness or lowering the costs of monitoring the large tracts of America’s forests, a vital natural resource that may play a key role in sequestering the carbon produced as a result of our current reliance on fossil fuels.

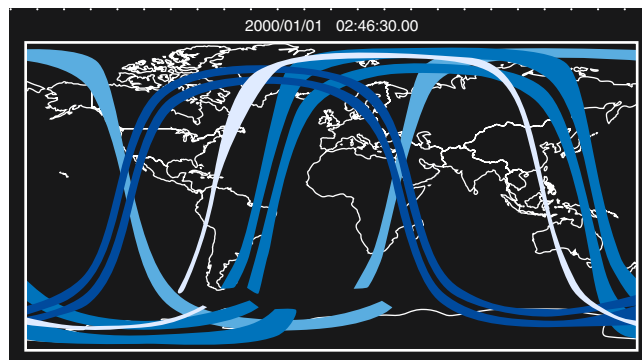
In related work by RAND’s National Defense Research Institute, S&TPI staff members have produced a report assessing the capabilities and limitations of national intelligence assets for environmental monitoring when it relates to key national interests



- Evaluates the adequacy of a new federal method for monitoring fine particulate material in air
- Finds that the new method has significant limitations—including the inability to conduct continuous sampling or to determine chemical composition—but that alternative technologies for overcoming these limitations are not yet available

Daily Orbital Tracks Illustrate the Strengths and Limitations of Satellite Based Observation

Science and Technology Policy Institute



- World-wide coverage within orbital limitations
- Episodic viewing of particular location

RAND

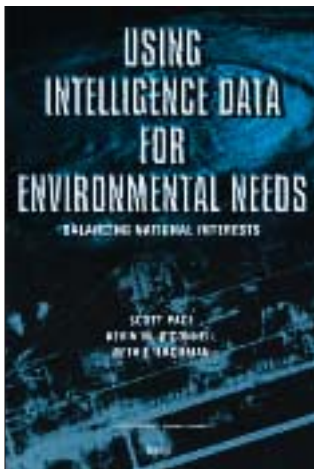
Single-satellite remote sensing systems have limited coverage if frequent monitoring is needed.

such as international negotiations on greenhouse gasses. A RAND report, *Using Intelligence Resources for Environmental Monitoring*, details their findings. It also illustrates one of the key features of the Institute—providing OSTP and other federal agencies a window into other RAND research that would not normally be known to the agencies but that could inform agency decisions.

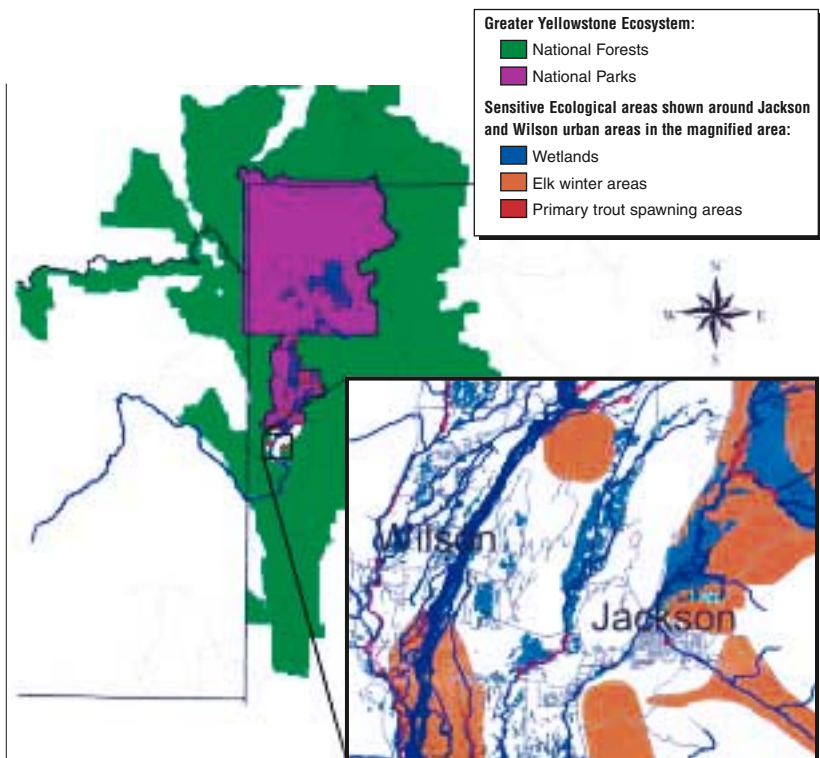
At the request of OSTP, RAND is developing an indicator system to assist federal, state, and local government natural resource managers within the Greater Yellowstone Area.

The system brings together diverse data from the various government agencies responsible for fishing, park

and forest administration, species management, and public recreation. It provides a shared, regionwide picture of the interrelated indicators that are necessary for managing resources, wildlife, public lands, and the environment. Information from this project will contribute to broader national efforts to develop indicators that signal the health status of ecosystems. The project also will contribute to federal efforts to use science and technology tools in working with state and local governments on environmental decisionmaking.



- Other RAND units conduct research of interest to federal science and technology policymakers.
- S&TPI provides a window into these other RAND activities.



S&TPI is prototyping the use of geographic information systems (GIS) to display and relate data on streams, fishing, large mammals and birds, vegetative cover, and community development. Such data are necessary for managing public lands and the environment in the Greater Yellowstone Area.

Related Publications

Beyond Command and Control: An Evolution Is Occurring in State and Local Government Environmental Activities. Beth Lachman. 1997. RP-642.

E-Vision 2000: Key Issues That Will Shape Our Energy Future: Analyses and Papers Prepared for the E-Vision 2000 Conference. James Dewar, Bruce Don, Jeff Drezner, John Friel, Anders Hove, Scott Hassell, Debra Knopman, Sally Sleeper, Rich Silberglitt, and Jerry Sollinger. 2001. CF-170/1-1-DOE.

E-Vision 2000: Key Issues That Will Shape Our Energy Future: Summary of Proceedings, Scenario Analysis, Expert Elicitation, and Submitted Papers. James Dewar, Bruce Don, Jeff Drezner, John Friel, Anders Hove, Scott Hassell, Debra Knopman, Sally Sleeper, Rich Silberglitt, and Jerry Sollinger. 2001. CF-170-DOE.

Forest Monitoring and Remote Sensing: A Survey of Accomplishments and Opportunities for the Future. D.J. Peterson et al. 1999. MR-1111.0-OSTP.

The Impact of Endocrine Disrupting Chemicals on Wildlife: A Review of the Literature 1985–1998. Sandy A. Geschwind, Elisa Eiseman, Dalia Spektor, and Arlene Hudson. 1999. MR-1050.0-OSTP.

Information Technology in the Home: Barriers, Opportunities, and Research Directions. Rosalind Lewis. 2000. IP-203.

Linking Sustainable Community Activities to Pollution Prevention: A Sourcebook. Beth E. Lachman. 1997. MR-855-OSTP.

Measures of Residential Energy Consumption and Their Relationships to DOE Policy. David Santana Ortiz and Mark Bernstein. 1999. MR-1105.0-DOE.

Monitoring for Fine Particulate Matter. Elisa Eiseman. 1998. MR-974-OSTP.

National Environmental Technology Strategy: Residential Construction Workshop. Thomas L. Anderson and Beth E. Lachman. 1996. P-7965.

The Role of Information Technology in Housing Design and Construction. Scott Hassell, Mark Bernstein, and Aimee Bower. 2000. CF-156.

Summary of Federal Construction, Building, and Housing Related Research & Development in FY1999. Scott Hassell, Scott Florence, and Emile Ettedgui. 2001. MR-1390-HUD/NIST.

Sustainable Food Production Workshop: Policy Options to Promote Environmental Technologies. Beth E. Lachman. 1996. P-7966.

Technology for a Sustainable Future—Ideas: A Summary of Workshop Discussions. Beth Lachman, Robert Lempert, Susan Resetar, and Thomas Anderson. 1995. RP-417.

Using Intelligence Data for Environmental Needs: Balancing National Interests. Scott Pace, Kevin M. O'Connell, and Beth E. Lachman. 1997. MR-799-CMS.

When We Don't Know the Costs or Benefits: Adaptive Strategies for Abating Climate Change. R.J. Lempert, M.E. Schlesinger, and S.C. Bankes. 1996. RP-557.

Emerging Governance Issues

Issues that require more government attention are emerging from rapid advances in science and technology. Developments in these fields cause issues to arise so quickly that they threaten to outstrip the response times and capabilities of traditional government structures. Among these challenges is the need to understand the evolving federal role in maintaining the national innovation system and managing it effectively, despite rapid change in the private sector and uncertainty about what is truly new about the nation's current economic performance. Another challenge is presented by what some call "game-changing technologies," such as cloning or micro-sensors, that may indelibly change our lives and our society in ways that could call for strong government oversight. Deciding on the appropriate role for government, however, and carrying that role out effectively, are exceedingly difficult because the developments are inherently global, responsibility for them is diffuse, and their impact is derived largely from the collective decisions of millions of consumers and citizens.

Stewardship of the U.S. Innovation System in a Global Context

The transformation of the U.S. economy over the past 20 years has made it clear that innovations based on scientific and technological advances have become a major contributor to our national well-being. The system that supports this process has emerged as one of our most important national assets, as important a source for growth today and in the future as have been in the past the nation's natural resource endowment, the talents and dedication of its workforce, and the accumulated stock of its capital goods.

Our understanding of innovative activity in the United States has also changed and grown more sophisticated. Discussion of innovation has shifted from a focus on products (identifying critical technologies, for example) to a focus on processes, from individual outputs to the mechanisms for producing those outputs. During this transition, the realization has grown that this system constitutes a dense and complex network of interconnected parts. The major actors in this system—the private sector, government agencies and labs, universities, the nonprofit research sector—relate to each other in complex

This interconnected network constitutes what has come to be called a national innovation system. Given the fundamental importance of this system to public welfare and the continuing importance of government as both a participant in and a provider of crucial elements of support, it is appropriate to understand what kinds of government actions (or for that matter, inactions) would contribute most to the continued development and health of the system, or detract from that development and health the least. There are three areas where the federal role in the innovation system is most clearly appreciated: managing the federal R&D portfolio; working with the private sector and universities as partners to enable innovation; and working in cooperation with our international partners on science and technology.

Next year, the U.S. federal government will invest more than \$90 billion to support R&D in government laboratories, colleges and universities, private firms, and other entities, many of which are increasingly international in scope. This investment is an essential source of fuel for America's high-tech economy. Effective management of the federal government's vast scientific enterprise is critical for achieving national goals and for ensuring that this large investment is wisely spent. S&TPI work in this area has focused on three areas: understanding the scope and effect of current R&D activities, priorities, and resource allocations;

Understanding R&D Investments—The RaDiUS Data System. One of the Institute's early efforts involved cataloging and describing information sources on the federal R&D activities. We found that policymakers lacked the kind of information tools required for a synoptic view of federal R&D. The only information available was incomplete and outdated. Historically, data on federal R&D were compiled retrospectively using traditional survey techniques, yielding information that was



- analyze R&D programs,
- find potential R&D partners,
- prepare strategic plans,
- identify transferable technologies,
- benchmark technologies,
- profile R&D activities, and
- optimize R&D investments.



- Provides the first complete accounting of federal spending on R&D in every state
- Informs members of Congress about the significance of spending in their individual districts

often two to three years old at the time of its release. To complicate matters, agencies often did not follow a standard format in reporting R&D information. The result was a fragmented and partial picture of federal R&D.

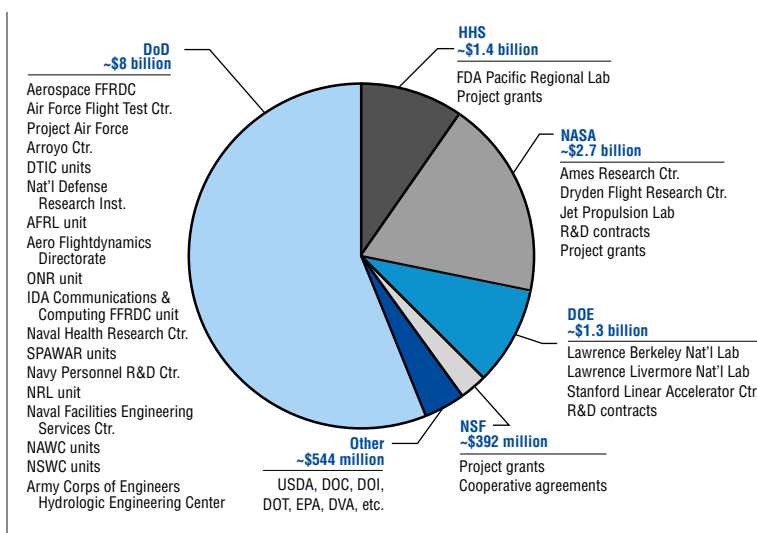
To help address this problem, RAND built RaDiUS (“Research and Development in the U.S.”), the first comprehensive, real-time data system for federal R&D activities and spending. This entailed identifying the various existing federal data sources that contained information on R&D; developing an organizational framework that allowed merging these data into a common, relational data system; and then creating an easily searchable Web-based data system containing detailed infor-

mation on federal R&D spending and substantive activities.

Federal users have free access to the data system; other users pay a subscription fee, which helps offset the costs of maintaining and updating the system data.

Assessing the Impact of Federal R&D Across the United States. Effective stewardship of the R&D portfolio requires a synoptic understanding of how federal R&D spending and activities are distributed—both across scientific fields and geographic areas of the United States. Using RaDiUS, RAND prepared the first comprehensive accounting of all federal R&D expenditures in each of the 50 states. The report, entitled *Discovery and Innovation: Federal Research and Development Activities in the Fifty States, District of Columbia, and Puerto Rico*, highlighted the importance of federal investments in R&D in every region of the nation. For each state, the report identifies sources and amounts of federal investments, and it indicates where the investments are being spent.

While it is often assumed that such information is readily available within the federal system, such a report was not possible until the advent of the RaDiUS data system with its exhaustive cataloging of federal R&D programs and its sophisticated search algorithms. In a letter thanking the Institute for its publication, then Governor Bush expressed his appreciation for the work that went into assembling the information.



Assessing federal R&D spending in states like California has only been practical with the development of the RaDiUS data system.

Economic Consequences of U.S. International Technology-Transfer Policies. The United States is a net exporter of technology and technical knowledge. Because of concerns that this outflow of technology means that U.S. taxpayers in effect subsidize foreign R&D, a series of federal policies require agencies—principally the Departments of State and Defense—to monitor and in some cases restrict particular kinds of technology developed with government funding. The key question for U.S. policymakers is whether this technology outflow poses a problem for the United States and if a need exists for a stricter and more comprehensive set of restrictions. This study examined current U.S. policies and attempted to estimate the economic consequences of current technology transfers overseas.

The study found that it would be impractical to institute a government-wide system for monitoring and restricting overseas technology transfers. First, a review of the economic effects of technology transfer showed that it is not possible to estimate accurately the financial effect on the United States of the international transfer of government-sponsored technology. Moreover, the methods of transfer that might be monitored or restricted are also sources of the valuable, high domestic societal return to government investments in R&D. Finally, government agencies do not see international technology-transfer issues as central to their missions and are likely to see new requirements as constraints on their

ability to carry out their missions. The study recommended no major policy shifts but suggested minor changes in existing policy that would enhance the U.S. government's ability to trace and to capture the benefits of certain technical innovations.

Related Publications

Assessment of Fundamental Science Programs in the Context of the Government Performance and Results Act (GPRA). Susan E. Cozzens. 1995. MR-707.0-OSTP.

Discovery and Innovation: Federal Research and Development Activities in the Fifty States, District of Columbia, and Puerto Rico. Donna Fossum, Lawrence S. Painter, Valerie Williams, Allison Yezril, Elaine Newton, and David Trinkle. 2000. MR-1194-OSTP/NSF.

Economic Approaches to Measuring the Performance and Benefits of Fundamental Science. Steven W. Popper. 1995. MR-708.0-OSTP.

New Foundations for Growth: The U.S. Innovation System Today and Tomorrow—An Executive Summary. Steven W. Popper and Caroline S. Wagner. 2001. MR-1338.0-OSTP.

Techniques and Methods for Assessing the International Standings of U.S. Science. Caroline S. Wagner. 1995. MR-706.0-OSTP.

Working with Industry and Universities to Meet National Goals

Institute research has been instrumental in helping OSTP and federal agencies develop strategies for partnerships with industry and universities that are designed to exploit the comparative advantages of the government, academia, and private-sector components of the national innovation system.

Understanding Industry Partners.

S&TPI has conducted several studies to examine new technology needs in various industries. The first report in this series responded on behalf of OSTP to a request from Congress to report on the state of the U.S. technological enterprise. The resulting report, *New Forces at Work: Industry Views Critical Technologies*, drew from interviews with top executives for 19 lead-

ing U.S. companies. The report conveyed perspectives on what technologies are essential for continued growth in key industry sectors and U.S. performance in fostering development or improvement of those technologies. The analysis also captured industry views on

- the status of key technologies (such as software, microelectronics, and advanced manufacturing systems);
- areas of concern across multiple industry sectors; and
- emerging technologies (such as biotechnologies) deemed most likely to transform society in the future.

In addition, the report served as the basis for a K–12 national technology literacy program developed by the University of Central Florida and available on the Internet. Through this program, students learn about ways in which science addresses real-world problems. The *New Forces at Work* report provides the basis for students to choose a technical focus.

The second report in this series, *Technology Forces at Work: Profiles of Environmental Research and Development at DuPont, Intel, Monsanto, and Xerox*, focused on innovation in the environmental-technology sector. The report advised OSTP on opportunities for public–private partnerships to develop environmentally friendly technologies and federal policies to foster investments in these technologies. The third study in the series, *New Forces at Work in Mining: Industry Views of Critical Technologies*, advised the National Institute for Occupational Safety and Health on leading technology trends in surface and underground



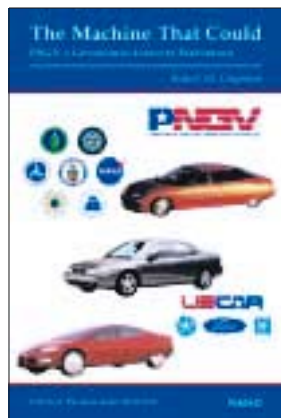
This series of studies examines the role that technology plays in U.S. industry. It

- responds to the congressional mandate that OSTP report on the status of critical technologies;
- provides the Executive Branch with perspectives of top industry leaders on which technologies are most critical to continued U.S. industrial strength in important sectors;
- informs state and local officials of critical technology trends from the real-world perspective of leading managers in industry;
- enables U.S. industry by ensuring that industry perspectives are considered in analysis;
- provides the basis for a unique K–12 science literacy program focused on how science is used to solve actual problems in industry; and
- benefits U.S. industry by helping technology developers and suppliers understand trends and attitudes in the industries they serve.

mining operations. The findings of this report are being used to identify emerging occupational risks and long-term priorities for federal research aimed at improving worker health and safety.

New Approaches to Public–Private Partnerships. The Institute analyzed the key elements of an innovative part-

nership between the National Laboratories and the Big Three U.S. automakers in a program to create a high-efficiency, low-emissions automobile for world markets. The resulting report, *The Machine That Could: PNGV, A Government–Industry Partnership*, identified management principles underlying the success of the early years of the partnership. Key among these were a clear, easily understood goal (a car that gets 80 miles per gallon by the year 2004); strong support at the highest levels of the administration; highly motivated industry partners; and strong public support. RAND’s analysis emphasized that essential elements for the success of the program were (1) industry (rather than government) technical leadership and (2) consolidation of related government activities under one “virtual” program.



- Provides an objective review of a public–private partnership to develop a safe, high-mileage family car
- Identifies factors in the early success of this program
- Advises on ways (industry technical lead, government budget coordination for “virtual” programs, and others) to ensure continued success

The Government Role in World Wide Web Standards. The White House was concerned that the rapid growth of the Internet and World Wide Web might require new standards for specific sectors of the digital industry. OSTP asked S&TPI to examine the need for improved standards and to assess what role the government might play in helping to develop these. *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy* offers the first comprehensive assessment of standards related to the digital economy, including Web standards, programming standards, digital library standards, standards for property and privacy, and standards for ensuring security between buyers and sellers in electronic commerce. The study concluded that government best plays only



- Assesses the need for more extensive government involvement in development of standards to govern the digital economy
- Provides the first comprehensive review of existing standards for all sectors of the digital economy
- Concludes that the appropriate role for government is very limited



- Addresses concerns from Congress about increases in university overhead costs
- Finds that university overhead costs are lower than corresponding costs in the federal government and private industry
- Demonstrates that universities share substantially in these costs, providing the federal government with a benefit of \$0.7 to \$1.5 billion annually

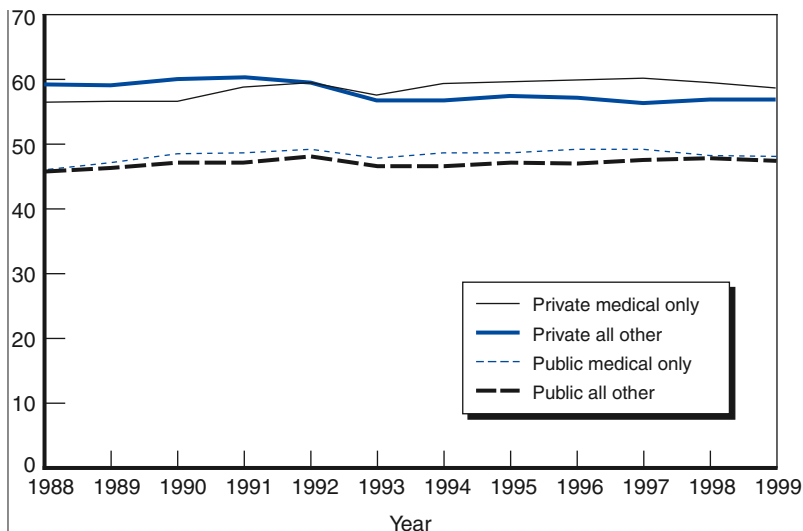
a minor role; the existing private-sector process “remains basically healthy.” The lead researcher for the project presented his findings in testimony before Congress.

Strengthening the Government–University Research Partnership.

Government funding of basic research conducted by universities has a long, and many believe successful, history. However, sensational reports of overcharges and other abuses at a few research centers in the early 1990s raised questions about proper accounting procedures and whether universities were paying their fair share of overhead. Responding to a mandate from Congress, S&TPI studied trends in research university overhead costs. *Paying for University Research Facilities and*

Administration evaluated the role of indirect costs in research and assessed policy options, providing the needed background for OSTP to answer questions from Congress. The report found that, on average, universities recover less than they are entitled to under current procedures: between \$0.7 and \$1.5 billion annually.

The report provided the basis for an executive order by the president that went into effect in 2000. The order was aimed at strengthening the partnership between the federal government and research universities. Other work by RAND also authored by the S&TPI team leader includes two books addressing additional aspects of the role universities play in the national innovation system. The first, *In Pursuit of Prestige*, describes the capital investments and other costs incurred by universities when they set out to build a first-tier research capability and reputation. The second, *The Ph.D. Factory*, addresses the capabilities and limitations of the nation’s current system for developing scientific and technical human capital.



SOURCE: Database compiled from the Office of Naval Research and U.S. Department of Health and Human Services, 1999.

A study of university facilities and administration charges to the federal government shows differences between rates charged by public and private institutions. OSTP requested this analysis in response to a mandate from Congress.

Related Publications

The Decline of the U.S. Machine Tool Industry and Prospects for Its Sustainable Recovery: Vol. 1. David Finegold et al. 1994.

MR-479/1-OSTP.

The Decline of the U.S. Machine Tool Industry and Prospects for Its Sustainable Recovery: Vol. 2, Appendices. David Finegold (ed.). 1994.

MR-479/2-OSTP.

The Machine That Could: PNGV, A Government–Industry Partnership. Robert M. Chapman. 1998. MR-1011-DOC.

New Forces at Work in Mining: Industry Views of Critical Technologies. D. J. Peterson, Tom LaTourrette, and James T. Bartis. 2001.

MR-1324-OSTP.

New Forces at Work: Industry Views Critical Technologies. Steven W. Popper, Caroline S. Wager, and Eric V. Larson. 1998.

MR-1008-OSTP.

Paying for University Research Facilities and Administration.

Charles A. Goldman and T. Williams. 2000. MR-1135-OSTP.

Technology Forces at Work: Executive Summary. Susan Resetar. 1999.

MR-1068/1-OSTP.

Technology Forces at Work: Profiles of Environmental Research and Development at DuPont, Intel, Monsanto, and Xerox. Susan Resetar. 1999. MR-1068-OSTP.

Linking Effectively with Our International Science and Technology Partners

International Cooperation in R&D.

By several measures, the conduct and outputs of scientific research and technology development are increasingly the result of international collaboration. Papers coauthored internationally rose from 17 percent in 1981 to 29 percent of all scientific papers published in 1995. International business R&D alliances are up more than eightfold since the mid-1980s. From 1987 to 1995, U.S. firms' investment in overseas R&D increased more than

twice as fast as did company-funded R&D performed domestically.

The increasingly global nature of R&D raises difficult questions for any national approach to investment in science and technology. Should nations identify specific areas of science and technology for national support when it is uncertain where R&D will be conducted and whether it will be exploited domestically? Is international cooperative research and development (ICRD) serving national goals when the knowledge and expertise associated with it are distributed and dispersed? Does it



- Responds to concerns about taxpayer benefits of U.S. spending on science and technology research
- Estimates total U.S. federal investment in collaborative international science and technology research, as well as breakdown of federal spending on different types of international collaboration
- Provides a recommended framework for assessing the benefits to U.S. taxpayers of these investments

matter where R&D funds are spent? Can we be sure that the U.S. taxpayer is benefiting from ICRD? Does our ICRD portfolio complement or compete with domestic spending?

To understand the role of ICRD in benefiting the United States and in supporting national goals in a global context, a number of building blocks must be put in place, including

- how much the United States spends on ICRD;
- which agencies spend it; and
- where the funds are being spent.

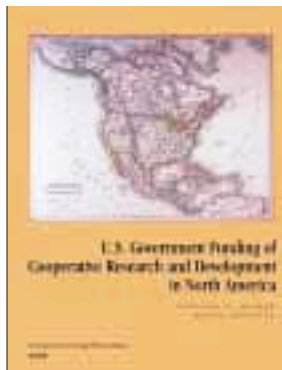
S&TPI has undertaken a number of studies to explicate ICRD and to improve U.S. government management of these relationships. In 1997, RAND assembled the first comprehensive profile of the nature and scope of U.S. spending on ICRD. A subsequent report in 2000 updated this information and set it in the context of current trends in global scientific research. A 2001 study has been examining and identifying lessons learned from effective international linkages in science and technology. The lead researcher on these projects has testified before Congress on the findings of these reports, and a number of government agencies have begun collecting and reporting specifically on international activities as a result. Guidelines for more effective collaboration, based on RAND research, have been drafted by several agencies of government.

Two reports in particular—*International Cooperation in Research and Development: An Inventory of U.S. Government Spending and a Framework for Measuring Benefits* and its follow-up, *International Cooperation in*

Research and Development: An Update to an Inventory of U.S. Government Spending—provide a total dollar estimate of how much the United States government is investing in international scientific research and identify trends over time. The latter of these reports documents a total fiscal year 1997 spending of \$4.4 billion—roughly 6 percent of the total federal R&D budget for that year, and a marked increase over the \$3.3 billion from fiscal year 1995 documented in the earlier report. The reports were used for White House assessments of costs and benefits of international investments in response to increasing pressure to document the benefits for taxpayers of federal spending on science and technology. They also provided background for the United States to use in negotiating international agreements related to science and technology. Several foreign governments have since sought to prepare similar reports on their own international science and technology research investments.

Research Cooperation with Mexico and Canada. To better inform the ongoing relationship between the United States, Canada, and Mexico in science and technology, S&TPI was asked to conduct a comprehensive analysis of science and technology cooperation in North America. The study team analyzed the current funding levels for cooperative research, assessed the types of collaborations undertaken among the three countries, and outlined options for optimizing

the evolving research relationship among the three countries. The research results provided the basis for discussions between the president's science advisor and his counterpart in the Mexican government. These high-level discussions focused on areas in which both countries wanted to increase the scientific exchange between the two nations. The effort has also served as the intellectual basis for a multination cooperative effort by the United States, the European Union, Canada, Korea, and Japan to identify "best practices" for international collaborative research. The study's findings have been published in *U.S. Government Funding of Cooperative Research and Development in North America*.



- U.S. spending on cooperative research activities with Canada and Mexico has averaged \$100 million per year since 1993
- Most of the collaboration focuses on addressing common interests and problems in several fields, including environmental, agricultural, earth science, and biomedical research

Related Publications

- Global Science and Technology Information: A New Spin on Access.* Caroline S. Wagner and Allison Yezril. 1999. MR-1079-NSF.
- International Agreements on Cooperation in Remote Sensing and Earth Observation.* Caroline S. Wagner. 1998. MR-972-OSTP.
- International Cooperation in Research and Development: An Inventory of U.S. Government Spending and a Framework for Measuring Benefits.* Caroline S. Wagner. 1997. MR-900-OSTP.
- International Cooperation in Research and Development: An Update to an Inventory of U.S. Government Spending.* Caroline S. Wagner, Allison Yezril, and Scott Hassell. 2001. MR-1248-OSTP.
- Techniques and Methods for Assessing the International Standings of U.S. Science.* Caroline S. Wagner. 1995. MR-706.0-OSTP.
- U.S. Government Funding of Cooperative Research and Development in North America.* Caroline S. Wagner and Nurith Berstein. 1999. MR-1115-OSTP.

Dealing with Game-Changing Technologies

Developments in science can also mean unanticipated challenges for the federal government. Among the most disruptive are challenges presented by what some call “game-changing” technologies—those that may indelibly change our lives and our society in ways that may call for a strong government role. Should the government regulate cloning techniques? Does it make sense to tax Internet-based commerce? Will nanotechnology provide breakthroughs that will revolutionize national security? Is the Internet a threat to personal privacy or to children?

The concerns raised by new technologies are often stark. But determining what the future direction of technology development will be, as well as deciding on the appropriate government role, is exceedingly difficult because of the deep uncertainty created by the game-changing nature of these technologies. To help inform government decisionmakers in anticipating such changes, S&TPI has consulted widely with scholars, researchers, and industry representatives to discuss emerging technologies in a number of forums.

Analytic Support for the National Bioethics Advisory Commission (NBAC). The United States increasingly faces governance questions stemming from the rapid and profound changes occurring in the bioscience and biotechnology arena. As a result, the president appointed a high-level board, the NBAC, to advise him on issues associated with advances in these areas. S&TPI has provided analytic

support to NBAC and OSTP as part of its research program and through the assignment of a member of the S&TPI staff to the NBAC staff. S&TPI provides a trusted, independent, and objective source of analysis to complement the perspectives presented by the other stakeholders in this community.

With the announcement that scientists in Scotland had successfully cloned an adult sheep, the president requested NBAC to report to him on the implications of the use of this technology to clone human beings. At the time, five states and several countries had prohibited the cloning of human beings. S&TPI’s analysis for NBAC—reported in *Views of Scientific Societies and Professional Associations on Human Nuclear Transfer Cloning Research* and in *Cloning Human Beings: Recent Scientific and Policy Developments*—provided the basis for NBAC’s report and recommendations to the president on human cloning.

Similar analysis helped inform NBAC and OSTP about the science of embryonic stem cell research. NBAC published the results of this analysis in its reports to the president, which are entitled *The Ethical Use of Human Stem Cells in Research*.

The Governance Challenges of the Infotech and Biotech Revolutions. A study group conducted by RAND consultant Francis Fukuyama and Caroline Wagner assessed the potential effect on governance of the emergence of information and biological technologies. The working group invited leading thinkers from many professions to hear a presentation and discuss a single aspect of information or biological technologies. The resulting report,



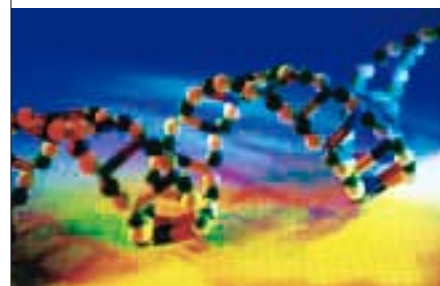
- Research informs the president on scientific and policy developments related to the potential for cloning of human beings.
- The most recent update helps inform NBAC on new developments in human cloning research.

The Global Governance of Information and Biological Revolutions, has been widely circulated among policymakers and academics.

Technological Change and the Environment. Technological change and scientific advancement in fields such as genomics, information technology, and remote sensing portend complex, and perhaps profound, transformations in how we relate to and manage our environment. To provide some insights into the range of possibilities on both the positive and negative side of the ledger, S&TPI has published a forward-looking, magazine-like report on the World Wide Web that examines poten-

tial transformations that are likely to produce significant changes in the next 10–15 years. The aim of the document is not to predict the future but to help prepare for inevitable change and the pressures and opportunities it is likely to create. Presented as a series of reflective essays by leading thinkers, the document examines how current and impending processes of change in our society, institutions, and technological world may affect our environment.

Our Future—Our Environment addresses such topics as the genetic and information revolutions, changes in the nature of production, fundamentally different models for managing the environment, and the challenges of global environmental governance. It is accessible at www.rand.org/scitech/stpi/ourfuture/.



Gains in computing power and biological insight have begun to converge, giving us the opportunity to learn our own genetic code and a start at understanding what it means. Some suggest that genomic technologies will move the frontiers of environmental protection inside the human body.

Related Publications

Can the Conventional Models Apply? The Microeconomics of the Information Revolution. Bruce W. Don and David Frelinger. 1996. RP-482.

Cloning Human Beings: Recent Scientific and Policy Developments. Elisa Eiseman. 1999. MR-1099.0-NBAC.

Information and Biological Revolutions: Global Governance Challenges—Summary of a Study Group. Francis Fukuyama and Caroline S. Wagner. 2000. MR-1139-DARPA.

Monitoring and Controlling the International Transfer of Technology. James Bonomo et al. 1998. MR-979-OSTP.

New Methods for Robust Science and Technology Planning. Robert J. Lempert and James L. Bonomo. 1998. DB-238-DARPA.

"Revolutionary Adaptations: Science and Technology in International Relations." Bruce Don. *Harvard International Review*. Vol. 21, No. 3. Summer 1999.

The Role of Technology Standards in Today's Society and in the Future. Martin C. Libicki. 2000. CT-172.

Views of Scientific Societies and Professional Associations on Human Nuclear Transfer Cloning Research. Elisa Eiseman. 1997. MR-881.0-CTI.

S&TPI Seminar Series

For its recent series of seminars, S&TPI identified cutting-edge scientific and technological advances and invited world-renowned researchers to brief the Washington policy community. The idea behind the seminar series was to bring scientists and engineers performing hands-on research with state-of-the-art technology in lab settings to a knowledgeable, Washington-based audience to discuss the emerging policy implications of such advances. Over the course of 30 seminars, RAND hosted more than 2,000 guests to discuss many of the most disruptive, and exciting, new technologies including

- remote sensing technology and applications
- nanotechnology, micromachines, and sensing
- biosensors
- combinatorial chemistry
- quantum computing
- computer-based speech recognition
- agricultural biotechnology

The Impact of Science and Technology on the International Political System. Writing a special essay for the 20th anniversary issue of the *Harvard International Review*, the S&TPI director analyzed some potential changes to the international political system brought about by changes in science and technology. The article notes that advances in science and technology may fundamentally change the “way the world works” in surprising and unanticipated ways. These advances have the potential to redefine the actors on the international stage and change their objectives in dealing with others. They can also change the nature of conflict, commerce, and international politics.

Advances in science and technology have the ability to reshape the power and influence of nongovernmental organizations, nation-states, and international organizations. Information technology and the low cost of communications have increased the number and kind of organizations with whom nation-states must deal. This is causing a fundamental change in the mechanisms of politics at the international level. Military technology is perhaps the most discussed aspect of this change. The lethality of conventional weapons has shifted the calculus of conflict and motivates a search for covert and surreptitious means of engaging adversaries. As advances in technology change sources of political, military, and economic power, the “valuable terrain” that is often the objective of conflict may change, and issues such as privacy or intellectual property rights may become major axes of contention. Shifts in the nature of

commerce are also becoming apparent. Information technology, with its digital representation of information, underwrites the ability to produce multiple copies of products at very low cost, potentially changing the nature of markets to favor the growth of monopolies. Reproduction and growth of biotechnology products, and self-assembly in nanosystems, may result in similar changes to the economics that underlie our economy and our businesses.

A modern world shaped by technology increasingly faces issues beyond the average person’s ability to understand through everyday experience. This makes typical approaches to formulating policy and strategy more likely to produce results that are either ineffective because of changing circumstances or hurtful because of unintended consequences. The effects of this development are (1) an increasing need to rely on scientific and technical knowledge in developing policies and (2) a need to take a different approach in policy formulation to address the uncertainty inevitably brought about by scientific and technical change.

Faced with such fundamental changes, we need to find ways to examine more carefully the *range* of possible changes and choose policies and strategies that are *robust*, given uncertainty and the possibility of rapid change.

Recent Non-RAND Publications

The S&T Policy Institute also contributes to documents published by government agencies and organizations other than RAND. The following listing shows examples of such documents.

Ethical Issues in Human Stem Cell Research, Volume I, *Report and Recommendations of the National Bioethics Advisory Commission*. National Bioethics Advisory Commission. September 1999.

Ethical Issues in Human Stem Cell Research, Volume II, *Commissioned Papers*. National Bioethics Advisory Commission. January 2000.

Ethical and Policy Issues in International Research: Clinical Trials in Developing Countries, Volume I, *Report and Recommendations of the National Bioethics Advisory Commission*. National Bioethics Advisory Commission. April 2001.

Ethical and Policy Issues in International Research: Clinical Trials in Developing Countries, Volume II, *Commissioned Papers*. National Bioethics Advisory Commission. May 2001.

Ethical and Policy Issues in Research Involving Human Participants. National Bioethics Advisory Commission. (Forthcoming.)

Research Involving Human Biological Materials: Ethical Issues and Policy Guidance, Volume II, *Commissioned Papers*. National Bioethics Advisory Commission. January 2000.

Other Selected Non-RAND Publications

Cloning Human Beings, Volume I: *Report and Recommendations of the National Bioethics Advisory Commission*. National Bioethics Advisory Commission. June 1997.

Cloning Human Beings, Volume II: *Commissioned Papers*. National Bioethics Advisory Commission. June 1997.

Investing in Our Future: A National Research Initiative for America's Children for the 21st Century. National Science and Technology Council Committee on Fundamental Science, Committee on Health, Safety, and Food, Executive Office of the President, Office of Science and Technology Policy. 1997.

National Critical Technologies Panel—Second Biennial Report. Office of Science and Technology Policy. 1993.

National Critical Technologies Report (1995 Biennial). Office of Science and Technology Policy. 1995.

National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility. National Science and Technology Council Committee on Technology Subcommittee on Transportation Research and Development. November 1999.

Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation. Office of Science and Technology Policy. 1999.

Report to the President on Federal Energy Research and Development for the Challenges of the 21st Century. President's Committee of Advisers on Science and Technology Panel on Energy Research and Development. November 1997.

Technology for a Sustainable Future: A Framework for Action. National Science and Technology Council Environmental Technology Strategy Staff, Office of Science and Technology Policy. 1994.

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REVIEWS FROM S&T POLICY INSTITUTE PROJECT SPONSORS

“The Science & Technology Policy Institute is a valuable resource for the Office of Science and Technology Policy, the National Science and Technology Council, and the President’s Committee of Advisors on Science and Technology. Bruce Don and his staff at the S&T Policy Institute have worked closely with us on a number of important issues.”

—Advisor to the President for Science and Technology

“A remarkable piece of work in such a short amount of time . . . This study . . . exceeded my expectations and is a clear and compelling argument for the need for an OSTP initiative in crime technology.”

—White House Office of Science and Technology Policy

[S&TPI’s principal investigator] “has been a remarkable project leader for the several National Bioethics Advisory Commission reports she has helped write. Her ability to synthesize complex materials has been appreciated by both commissioners and staff.”

—President’s National Bioethics Advisory Commission

“After reading this study . . . lawmakers at the local, state, and national level have advised us that they have developed a new appreciation of the continuing contributions that our R&D investments make towards achieving our overarching goals of economic growth and national security.”

—White House Office of Science and Technology Policy

“We appreciate the excellent, cooperative work of S&TPI staff and the high-quality capabilities and knowledge employed on this project.”

—National Science Board

“RaDiUS is the first data system that systematically links the high-level R&D information presented annually in the President’s budget to the hundreds of thousands of actual studies, experiments, and analyses conducted by scientists with federal R&D funds. As a result, RaDiUS provides the most complete picture of federal activities involving the conduct of R&D ever available.”

—White House press release

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