ANNUAL 1997 REPORT

RAND

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The Critical Technologies Institute is a federally funded research and development center operated by RAND, a nonprofit institution that helps improve public policy through research and analysis.

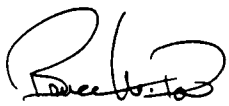
RAND

DIRECTOR'S FOREWORD

As CTI marks its fifth birthday in 1997, it is worthwhile to reflect on how far we have come as an institution since those first studies got under way in 1992. A continuing theme in CTI's history has been adaptation—more specifically, adapting our research agenda and approach to make the optimal contribution in a complex policy environment. As we note in the introduction, CTI was the product of multiple visions—including those of the White House, Congress, the National Science Foundation (NSF) and RAND—of what a federally funded center for the analysis of science and technology policy ought to be. Perhaps our greatest challenge as an institution has been to harmonize these visions. Doing so has involved a continual balancing act: maintaining a close and confidential relationship with the principal consumer of our research, the White House Office of Science and Technology Policy, and providing them with timely and responsive research and analysis while also upholding RAND's traditions of analytic objectivity and methodological rigor; meeting the high standards of accountability and program efficiency demanded by our principal funding agency, NSF; and, finally, honoring the congressional vision of CTI as an abiding national resource above the fray of partisan politics.

One measure of our success in accomplishing this has been our contribution to specific policy decisions. There are several examples of such impact, at all levels of government and in the private sector. For instance, CTI research has informed eight presidential level initiatives, including an initiative focusing on how science and technology can help with child development (see p. 21). In addition, our research and analysis have supported policy decisions that have empowered private industry. A prime example has been our analytic support for the Partnership for a New Generation of Vehicles.

Another measure of our success has been a vote of confidence from the U.S. Congress, which, as we went to press with this report, passed legislation changing our name to the Science and Technology Policy Institute and expanding our mandate specifically to reflect our contributions to science as well as technology policy. We look forward to the continuing challenge of contributing to policymaking in these vital areas under our new banner.



Bruce W. Don
Director

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I. CTI: THE FIRST FIVE YEARS

The Critical Technologies Institute (CTI) was chartered by Congress in 1991. Its creation was the culmination of decades of debate and discussion within the government and the U.S. scientific community about the need for an organization to conduct independent and objective research and analysis in support of federal science and technology policymaking. CTI was the product of four complementary visions of how to fill that need. These came from Congress, the Executive Office of the President, Office of Science and Technology Policy (OSTP), the National Science Foundation (NSF), and RAND.

The congressional vision saw a need for an objective policy-research organization that could maintain a vision and agenda apart from political interests. Such an institution would require a dedicated, highly qualified research staff for continuity.

The executive branch had a slightly different set of needs. These included the need to maintain a close and confidential relationship with an analytic institution that would provide rapid response on issues; possess the capability to work with other agencies, state governments, academia, and private industry; and provide honest, trusted advice and support to OSTP.

A third interested party was the agency charged with advancing the progress of science in the United States: the National Science Foundation. The NSF sought stewardship to provide checks and balances to counter the pull of political exigencies, ensure quality research, enforce cost-effectiveness, and provide proactive guidance and support.

Finally, RAND brought yet another set of expectations. RAND emerged as the winner in a competitive bidding process for the CTI contract. RAND envisioned an institution that would provide analysis and information support on the nature and state of science and technology (S&T) policy in order to address critical national issues. To this effort, RAND would bring a diverse experience, including 40 years of studying defense policy issues, over two decades studying domestic and international policy issues, and a strong track record of providing candid information and advice to government research sponsors. For RAND, the key characteristics of a quality research institution centered on identifying policy alternatives, asking the "right" questions, and doing objective thinking.

RAND's Critical Technologies Institute, which began operation in 1992, was an attempt to blend these visions of how an independent research organization could best support the analytic needs of the government S&T policy formulation. Blending these different perspectives, in particular balancing the RAND vision with OSTP's needs, has been a continuous learning process. Requests for information did not as a rule arrive at

CTI in a form to which RAND was accustomed—that is, provide policy alternatives, or make sure policy formulation is addressing the right question, or provide confidential advice on high-level issues. Rather, requests tended to arrive in a slightly different context, asking for

- insight into cross-government operations
- data on science and technology
- direct support of presidential policy decisions
- institutional memory.

As RAND/CTI adjusted to these request modes, CTI's mission refined itself to address those areas where its impact could be maximized. These areas concerned high-profile issues of science and technology policy that involve or affect multiple executive branch agencies or different branches of the U.S. government, or involve interaction between the U.S. government and other nations or the private sector.

To this evolving mission, RAND brought a unique set of characteristics. These included its reputation as an "honest broker" and confidante to both government and business and an established set of connections and access to decisionmakers; a multidisciplinary approach to analysis with its foundation in fact-based, objective research focused on policy applications and a decades-long orientation toward resource allocation; experience with a research center and the means to invest in and nurture its growth; and a "bench" of over 600 professional staff plus access to approximately 8,000 consultants.

RESEARCH ACTIVITIES

CTI's annual research plan is developed interactively with OSTP. It consists of three activities: analytic tasks, core support efforts, and analytic tool development. A fourth activity, maintenance of the RaDiUS™ R&D data system, is conducted in cooperation with NSF and is funded by user subscriptions. (See Figure 1.)

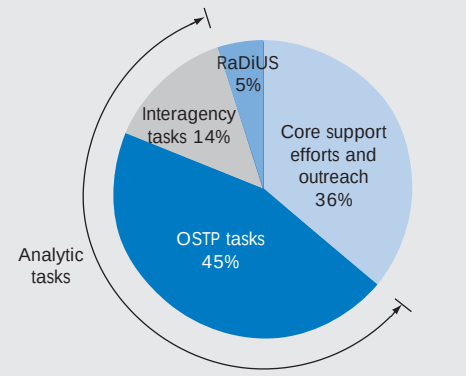

Figure 1—CTI Research Tasks by Type

Analytic Tasks

Analytic tasks are the specific, deliverable-oriented blocks of the Research Program. They are the primary mechanism through which CTI informs policymakers in OSTP and provides a public record of its analysis. Tasks may be conducted in support of OSTP, NSF, or other agencies when a policy question is interagency in nature.

Experience with CTI research over the past five years has identified five issue areas in which RAND's capabilities most effectively meet the needs of OSTP and other supported offices, agencies, and councils of the executive branch. These areas are:

1. Health and the environment. There is a heavy emphasis currently in the federal government on technological approaches to solving environmental problems.
2. Space and transportation. This is the "biggest" science enterprise. The figures for nondefense R&D clearly illustrate the rationale for this and the previous issue area.
3. Critical infrastructure and technology. This issue area is designed to cut across canonical budget lines. Critical infrastructure and information technology, as such, do not appear separately in the usual breakdowns. Yet, this is a crucial cross-cutting area of concern that provides the context for much of what is emerging in all areas of science and technology.
4. Education and training. This area, the wellspring of prosperity, competitiveness, and S&T leadership, shows the importance of thinking beyond traditional budgeting and organizational boundaries. Although only a sliver of the formal R&D pie, issues of education and training affect all aspects of the U.S. innovative enterprise.
5. The R&D portfolio. Finally, there is value in having in place a structure capable of considering the federal R&D portfolio overall—as well as of taking closer readings of selected areas otherwise overlooked.

These five categories represent the bulk of CTI's policy-analytic efforts and resource expenditures. The level of effort attempts to strike a balance across the five task areas and take full advantage of the significant work under way in other parts of RAND, most notably in national security, education, and the nontechnical aspects of health care.

Core Support Efforts

In addition to research, CTI carries out support efforts necessary to underpin the research program. These "core" efforts include the activities of the Director and his immediate staff in conducting Institute operations and developing and managing the research program. They also include

- efforts associated with CTI's legislative charter, which requires it to consult widely with representatives from private industry, institutions of higher education, and nonprofit institutions
- activities to exercise sound financial control over the Institute's resources
- work on special projects to complement tasks and provide quick-response analytic support
- explorations of substantive areas of likely future concern to develop requisite analytic resources
- concept formulation research necessary to provide a forward-looking perspective that

can anticipate problems and issues and so preclude simply reacting to events.

Analytic Tool Development

The final component of the research program comprises work to develop new analytic methods and information systems that allow more cost-effective analysis in the future. These efforts attempt to provide tools that will pay dividends in the future to OSTP, across the government, and to the larger science and technology policy community.

This research program component may be thought of as CTI's R&D. As with other forms of R&D, there are associated risks. Additionally, some lead time is necessary to bring new methods and systems to maturity. Because of this, the level of effort for this component of the research program must reflect the need to ensure the right balance with more immediate analytic tasks.

CTI'S POLICY IMPACT

The measure of CTI's value both to the nation and to RAND appears most in our ability to help shape policy. A number of examples illustrate this impact:

- CTI research has informed five Presidential Decision Directives.
- CTI is supporting research on three Presidential Review Directives.
- CTI research has been the foundation for four policy statements issued by the National Science and Technology Council (NSTC).
- CTI has enhanced a dialogue between the executive branch and state and local governments and between OSTP and the private sector.
- CTI research has resulted in policy decisions that have enabled private industry.
- CTI databases are increasingly being viewed as the de facto standards for managing the federal R&D effort.

Figure 2 details the impact that a selected set of CTI tasks has had on policy as measured in five different dimensions: informing presidential-level decisions, informing agency and NSTC initiatives, supporting state and local efforts, enabling U.S. industry, and helping to shape analytically based standards. These tasks span the range of CTI's work and show substantial impact despite the need to address the broad research needs of our primary client.

In the many instances of informal, short-term contact, CTI has created a core competency of both functional knowledge and policy tools. CTI has also conducted objective cross-cuts of government activity at a fraction of the cost of previous cross-cuts, none of which could have been carried out at the agency level. CTI has played roles, produced work, and taken stands that are beyond the means of most contractors.

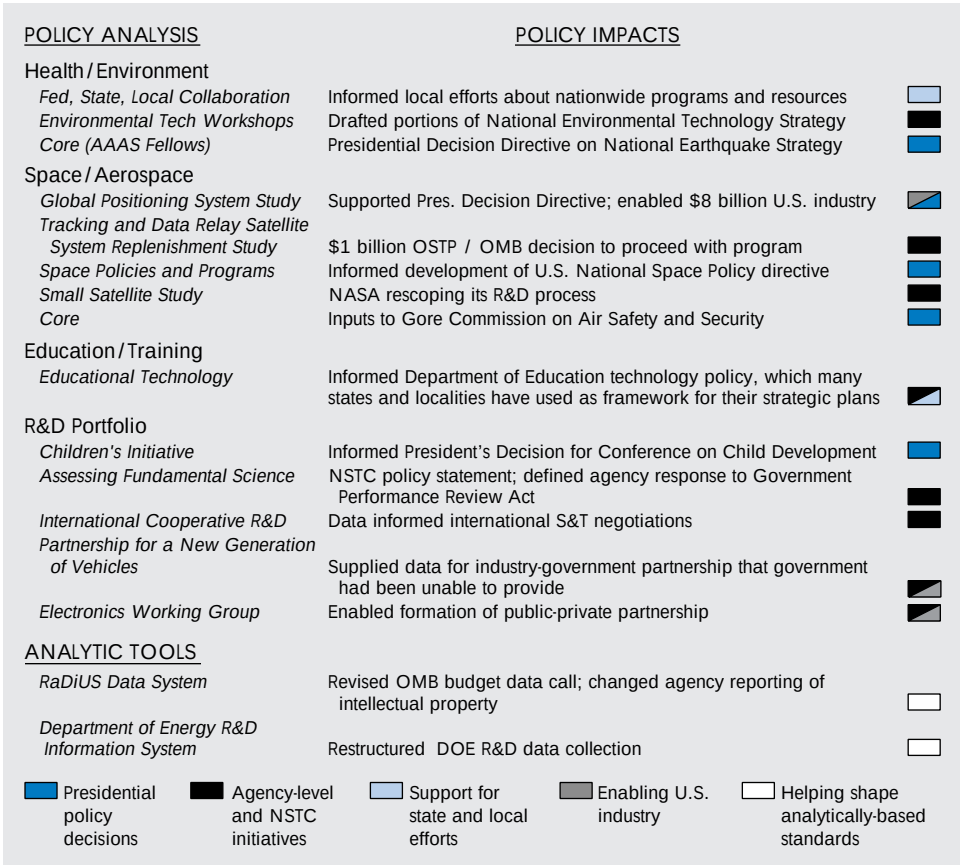

Figure 2—CTI's Policy Impact

ORGANIZATION OF THE REPORT

The sections that follow summarize CTI's research activities in 1997 according to the main areas of inquiry: environment and health; space and transportation; critical infrastructure and technology; technology in education and training; and the federal R&D portfolio. Each section summarizes the year's major projects and highlights a specific project in detail. Following these sections, we describe CTI's special activities and outreach programs, then provide a comprehensive list of CTI publications to date.

II. HEALTH AND ENVIRONMENT

SUSTAINABLE COMMUNITY ACTIVITIES AND POLLUTION PREVENTION

The "sustainable community" approach to community-level environmental problems is gathering momentum in the United States. This project examined the concept of "sustainability" and described the range of programs under way around the country (see highlight).

MONITORING TECHNOLOGIES FOR ENVIRONMENTAL REGULATION

New monitoring technologies are critical to the development of performance-based regulatory programs. However, the technical capability of these technologies is variable and in some cases unknown. Moreover, implementing these technologies in an evolving regulatory system poses many challenges. This exploratory project interviewed relevant federal agency personnel to characterize existing and emerging technologies for monitoring pollution. The interviews will be summarized in a nontechnical, unclassified report.

The investigation focused on technologies for monitoring for fine particulate matter, based on EPA's proposed revision of the National Ambient Air Quality Standards for particulate matter. We interviewed federal agency personnel to characterize existing and emerging technologies that may be used for continuous monitoring for fine particulate matter. We characterized the advantages of five different methods of monitoring, including EPA's proposed new Federal Reference Method for monitoring for fine particulate matter and commercially available monitoring technologies that could be used for continuous, real-time monitoring.

Publication: Elisa Eiseman, *Monitoring for Fine Particulate Matter*, MR-974-OSTP.

MONITORING TECHNOLOGIES FOR ECOSYSTEM MANAGEMENT: FEDERAL, STATE, AND LOCAL COLLABORATION

For this research project, CTI has been analyzing federal, state and local government collaboration in monitoring for ecosystem management. This research will provide input to the NSTC Committee on Environment and Natural Resources (CENR) and its National Monitoring Initiative for integrating the nation's environmental monitoring and related research networks and programs.

The methodology used for this analysis is a literature review and three in-depth case studies focused on monitoring programs with significant federal involvement. These case studies are focused on three diverse regions of the country in terms of ecosystems, federal involvement, and monitoring efforts. The

areas are the Chesapeake Bay region, Florida, and the Pacific Northwest. CTI has conducted in-depth interviews with state, local and federal government representatives in these three areas about their monitoring programs for ecosystem management and the lessons they have learned from collaborating with other levels of government. Through these interviews, this study has emphasized how federal agencies can more effectively work with their regional, state, and local partners in such monitoring efforts.

FEDERAL, STATE, AND LOCAL COLLABORATION IN ENVIRONMENTAL TECHNOLOGY DEVELOPMENT, DIFFUSION, AND IMPLEMENTATION

State and local government policies and activities play an important role in the development, diffusion, and implementation of environmental technologies. For this project, CTI analyzed relationships between federal, state, and local government efforts to promote the development and implementation of environmental technologies, with an emphasis on innovative regional, state, and local programs. Three main research topics are being addressed in this study:

1. How do state and local government activities and policies affect the development and use of environmental technologies?
2. What is the federal government's role in such activities?
3. How can the federal government more effectively collaborate with state and local governments in such activities?

CTI began the study by analyzing a wide range of state and local efforts that affect the development and use of environmental technologies, including R&D, demonstration, regulatory policies, financing, verification, economic development, promoting exports and market development, technical assistance, and pollution prevention assistance. The application of such technologies in infrastructure implementation, ecosystem management, and sustainable community activities was also addressed. In this research, CTI performed a general broad analysis of the current status and directions of such regional, state, and local efforts. This task included identifying commonalities and differences in objectives, themes, and approaches and understanding the relationships among the federal, state, and local governments.

Based on this initial analysis and OSTP needs, CTI chose three areas to analyze such issues in greater depth.

- State and local government innovative regulatory activities
- Monitoring for ecosystem management: federal, state, and local government collaboration
- Analyzing sustainable community activities and their relationship to pollution prevention efforts.

STATE AND LOCAL GOVERNMENT INNOVATIVE REGULATORY ACTIVITIES

State and local governments are implementing many innovative environmental activities to improve environmental performance and to lower the cost of compliance. These innovative activities include regulatory experiments and voluntary programs in partnership with many different stakeholders and in a wide range of environmental approaches and activities.

Many states are providing compliance assistance and passing auditing laws to make it easier for industry to be in compliance. Regional, state, and local pollution prevention (P2) voluntary programs, technical assistance activities, and state P2 planning laws are helping businesses save money and reduce the amount of pollution they generate.

Innovative facility and multimedia permitting and inspection programs are also being implemented to improve environmental performance and/or reduce the regulatory burden on industry. The U.S. Environmental Protection Agency (EPA) and the states have jointly developed the National Environmental Performance Partnership System (NEPPS), which allows for more state priority setting and innovation in implementing U.S. EPA delegated programs. Many states are exploring the potential regulatory benefits of industry's implementing environmental management systems such as ISO 14000. Regional, state, and local government sustainable community, ecosystem management, watershed management, and other place-based management approaches are other innovative ways to improve environmental performance. Many of these integrated place-based approaches have emphasized cooperation and collaboration of all stakeholders and have also included regulatory flexibility. Such state and local activities are helping to transform U.S. environmental policy and could change the nature of our future regulatory structure.

For this study, CTI has been analyzing such activities to better understand how they impact the development, diffusion, and use of environmental technologies. Another important emphasis has been understanding their current and future impact on environmental policy and the regulated community.

FRAMEWORK FOR COMPARING ENVIRONMENTAL R&D

Over the past few years, both public and private-sector organizations have been under pressure to cut back or reorient research dollars. In this constrained climate, meeting existing and future environmental goals will become more and more dependent on achieving an effective allocation of scarce R&D funds across the federal and private sectors. While federal research and development investments are an important policy tool, their magnitude pales in comparison to private investments.

To better structure its R&D priorities and policies, the federal government must develop a clear understanding of how research-intensive industries are rethinking investments in environmental management and technologies; where these industries are likely to invest, where they will not invest, and where there are opportunities for private–public sector partnerships; and how existing and future competitive pressures affect industrial environmental R&D strategies.

In this project, CTI is analyzing private-sector environmental research and development activities. The effort involves case studies of 4–5 firms in different sectors that have large R&D budgets, a history of innovative research, and a clear reputation as environmental leaders in the industry. This is an effort to ensure that private-sector concerns are addressed in federal policy.

RESEARCH HIGHLIGHT

SUSTAINABLE COMMUNITY ACTIVITIES AND POLLUTION PREVENTION

Communities in the United States have increasingly come to believe that environmental issues and other community problems cannot be addressed in isolation. Instead, many communities are confronting them as part of a broader approach to developing and achieving a healthy community by addressing economic, environmental, and social issues together. This new approach is typically based on the concept of "sustainability." Indeed, the growing popularity of the concept has prompted some to declare that a "sustainable community" movement is under way in the United States.

Despite its widespread use, the concept of a "sustainable community" is confusing. The term lacks a single, widely accepted definition. Likewise, the range of activities it encompasses has not been coherently mapped. Because most sustainable community initiatives are independent and unique projects undertaken at the local or regional level, there has been little broadly based effort to identify and categorize the various sustainability efforts nationwide. As a result, many communities are launching similar projects with limited awareness of what others are doing.

Furthermore, the relationship between sustainable community activities and other environmental efforts—especially pollution prevention—has not been closely examined. Consequently, individuals and organizations may have missed opportunities to exploit the synergy between pollution prevention and sustainable community activities or to learn from similar projects in other parts of the country.

A recent RAND/CTI study attempted to remedy this deficiency. The study examined and attempted to clarify the concept of a "sustainable community" and the principal

elements of sustainable community initiatives. The study also compiled information on these activities and described several such efforts in detail. Finally, it examined the relationship between sustainable community activities and pollution prevention, noted synergies between the two, and provided specific suggestions for how pollution prevention practitioners can take advantage of the sustainable community movement.

What Is a Sustainable Community Effort?

Hundreds of communities of all sizes and types across the United States are developing and implementing sustainability projects. The City of Seattle, for example, has explicitly incorporated sustainability concepts as part of its community planning and development, including a comprehensive initiative to address such urban problems as sprawl. In EcoVillage at Ithaca, New York, community members are building a new neighborhood on previously undeveloped land. The project incorporates sustainable principles and practices in the community design, buildings, and activities. Curry County, Oregon, a rural community whose economy has been based on logging and fishing, has a Sustainable Nature-Based Tourism Project to design, build, and implement a sustainable economic sector.

Relationship Between Sustainable Community Activities and Pollution Prevention

Pollution prevention involves changing policy, practices, behaviors, and/or processes to reduce pollution at the source before it is even generated. Such activities have been going on in this country for many years, frequently without any specific connection to sustainable community activities. Recently, pollution prevention efforts have begun to merge with sustainable community activities. This is true in large part because pollution prevention is a major building block for many communities' sustainability projects. Pollution prevention is frequently a goal or guiding principle for communities and may also provide a focus for specific activities. Moreover, the vision of sustainable community projects can provide a broader vision for pollution prevention activities. These pollution prevention activities are incorporated into the broader community perspective for developing a healthy community over the long term. Sustainability projects also offer a way of harmonizing industry, government, and general public efforts to address environmental issues, including pollution prevention activities. The CTI report points to a vast range of information and resources for pollution prevention practitioners and other individuals who want to implement more sustainable practices in their communities.

Opportunities to Increase the Success of Sustainable Community Activities

The sustainable community approach is an exciting experiment for addressing environmental and community problems. By analyzing these efforts and their relationships to pollution prevention activities, the author identifies the following general implications for taking full advantage of sustainability activities and potentially improving community health:

All levels of government have important roles to play in supporting sustainability efforts. As this fledgling "movement" grows and evolves, it is important that all levels of government provide encouragement and assistance.

Private-sector organizations and the general public also have critical roles. Businesses, nongovernmental organizations, and universities are among the organizations whose participation can be central to such activities.

Businesses, for example, are the cornerstone of eco-industrial park efforts. Community and environmental groups often generate significant public enthusiasm and support. Individual volunteers and the general public can also contribute significantly.

Collaboration and cooperation among the various players are key factors in sustainability efforts. Community members work together, often forming unique partnerships of individuals; environmental and other nongovernmental groups; industry and businesses; academia; and local, state, and federal governments. Most of these communities feel that only the combined skills and cooperative effort of all segments of the community can solve the unique and difficult problems that they face.

Government and private organizations need to break out of traditional stovepipe operating modes and take a broader view in balancing different interests and goals; across organizations, disciplines, and stakeholders; and in addressing environmental and other community problems. Many government and private organizations are accustomed to addressing environmental problems based on traditional media, organizational, or disciplinary perspectives. This new integrated approach often requires change in how individuals act and view others in government and other sectors of the community. For example, sustainability activities enable government pollution prevention practitioners to work more easily with individuals in other departments in addressing environmental and community problems. To address urban sprawl, the local environmental agency might work with the transportation, planning, and economic development departments, in addition to community groups, businesses, and other relevant stakeholders.

There is no single or simple mechanism to solve the community problems that sustainability projects address. Creating a sustainable community—a community

with comprehensive environmental, social, and economic health and stability for many generations to come—is difficult. Many problems may be solved only through a mix of policy mechanisms, actions, and technological solutions across a range of governmental departments and functional areas based on local conditions. Communities may focus on education, technology, development, and implementation or on changing the practices and behaviors of individuals, government, and/or businesses.

In addition, more systematic analysis of sustainable community efforts is needed. The CTI research represents a first step in this direction. We need a better understanding of how to measure programs' effectiveness, how to evaluate implementation strategies and progress, and how to transfer lessons learned. Conducting this work will present analysts with a difficult challenge. The highly individualized nature of each sustainable community project—reflecting localities' unique circumstances—complicates the task of quantifying, analyzing, and comparing projects. Confronting this challenge will help the evolution of sustainable community activities and increase their potential for success.

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

III. SPACE AND TRANSPORTATION

SMALL SPACECRAFT

Small spacecraft are now a key element of the civil space program. This study examined the major issues surrounding the growing reliance on small spacecraft and made recommendations for addressing them (see research highlight).

ANALYSES OF SPACE AND AEROSPACE POLICIES AND PROGRAMS

This long-term, direct support activity provides analysis of 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 is expected to be of a direct-assistance nature. The project will examine federal R&D plans, the conduct of government-industry partnerships, and ongoing civil and military space programs. Current efforts include analyses of funding options for government space activities and support for international consultations with Japan, the European Commission, and Russia on issues related to the Global Positioning System (GPS) and space technology–related trade.

Extensive efforts were made in support of interagency discussions to develop a draft U.S.–Japan Agreement on the Global Positioning System. Memos were prepared for OSTP and the Department of State on objectives, metrics, and strategy for negotiations with Japan, Europe, and Russia. A white paper on governmental barriers to the use of GPS technologies and services was prepared for OSTP and State.

COMMERCIAL RESOURCES FOR MISSION TO PLANET EARTH

NASA's Mission to Planet Earth (MTPE) is the largest U.S. government civil remote sensing effort. It is central to global climate change research, a priority concern of OSTP, and it is also under severe budgetary pressure. The ability of MTPE to achieve its scientific objectives may be threatened by funding reductions and instability. At the same time, there is an increasingly capable commercial space sector which may offer opportunities to leverage private resources to meet public objectives.

Crafting mutually beneficial arrangements requires addressing multiple policy, legal, and regulatory issues affecting government-industry cooperation in remote sensing. Such issues cut across multiple agencies—the Departments of Commerce, State, and Defense, as well as NASA. In particular, if MTPE is to leverage commercial remote

sensing resources, then attention to potential data policy issues in close government-industry partnerships will be needed.

This project is identifying current data policies, laws, and regulations that create barriers for MTPE scientists seeking to acquire data and services from the private sector. When this activity is complete, the project team will make recommendations on the removal of barriers, including alternative policies and legislation where appropriate. The research is being funded by NASA.

RESEARCH HIGHLIGHT

KEEPING THE SPACE PROGRAM ALIVE AND COSTS LOW

Small spacecraft have evolved to become a key element of the civil space program. In the wake of federal budget reductions, civil and military space programs have had to downsize. Small spacecraft are an important means of maintaining scientifically viable programs within tighter budgets. Within NASA, small programs also substantiate the

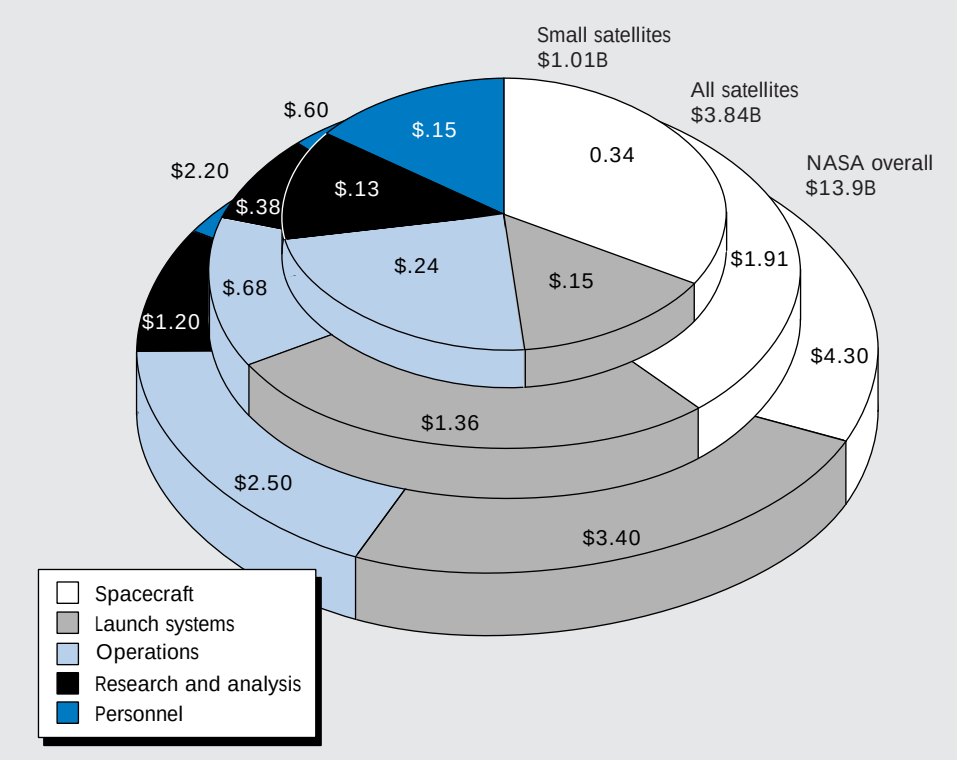

Figure 3—Satellite Budgets at NASA (FY96)

"faster, better, cheaper" management and design strategies created in response to the National Performance Review.

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. In the area 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 come to play a more central role in national space policy, it is important that decision-makers understand the dynamics of smaller programs and maintain realistic expectations of their potential. Developments related to small programs also offer new options in policy formulation and implementation.

With these thoughts in mind, OSTP and the Office of Management and Budget (OMB) asked RAND/CTI to undertake a study of small-spacecraft programs. The study identified several key issues and made recommendations for addressing them. The project used an interdisciplinary methodology that relied heavily on close interactions with the NASA offices responsible for conducting space research and the many supporting offices that develop technology and assist in the process of building and testing spacecraft.

The study identified four categories of issues: civil space-policy objectives, performance improvement, improvement of technology planning and implementation, and measurement of performance.

National Civil Space Policy Objectives

Profound change has swept through NASA in recent years. Funding constraints and the agency's changing role as a builder of space systems have altered the environment in which it operates. These changes suggest the need for a reexamination and reformulating of agency goals to balance cost-containment and program effectiveness aims while strengthening NASA's core competencies. Accordingly, the study recommended that the National Space Policy call for NASA to pursue mission excellence in the design and development of science spacecraft and also suggested an examination of NASA's roles and missions.

Improving Technology Planning and Implementation

NASA spends approximately 2 percent of its annual budget on spacecraft technology programs. To maximize returns from this modest investment, NASA in 1992 created the Integrated Technology Plan (ITP), an attempt to coordinate agency projects centrally. However, the plan lacked a clear methodology for managing technology development, a clear tie between projects and future mission requirements, and a means of evaluating success and failure. In 1996, NASA realigned its planning functions to place all responsibility for technology planning under a new Office of Technology. A central objective of this realignment was to refine and reissue the ITP. Of the many

factors complicating this task, perhaps most important is the challenge presented by the agency's dual mandate to conduct science and develop technology.

The study recommended that NASA make the Integrated Technology Plan a focal point for the coordination of all instrument, spacecraft, and ground-system technology initiatives and merge current spacecraft technology-development programs under the umbrella of the ITP.

Risk Measurement and Reduction

While the study found that, historically, science spacecraft have demonstrated increasing reliability, this trend might not continue with the current generation of small spacecraft. A consequence of the shift to managed risk is a greater potential for failure. Less money is generally available to smaller programs to test spacecraft functions and operational procedures prior to launch. Small spacecraft are also generally less robust. Consequently, policymakers should anticipate that failures will occur more frequently than in the past. This observation highlights the importance of NASA's research in the area of high-reliability systems. Efforts to reduce the potential for failure by applying more-reliable components, better testing, and advanced design techniques should receive greater attention.

The study recommended increased funding for efforts to improve quantitative measurement of risk and reliability. New risk measurement techniques should be designed to support not only the technical management of missions but also the need for NASA program offices to communicate risks to the policymakers.

NASA should direct additional funds to research in high-reliability space systems and to the study of failure analysis, new test practices, and advanced design processes. Finally, it should augment funding for test and evaluation of high-reliability mechanical systems for small spacecraft.

Measuring Performance

NASA rarely discusses risk-related issues with Congress and other policymakers. Policymakers can no longer assume that risks are being minimized and should be aware of the level of risk reduction that is being achieved with available funds. NASA's new managed-risk strategy carries with it both a need and an opportunity to communicate risk information more effectively.

Another key issue in evaluation of small spacecraft programs is formulating a response to the requirements of the 1993 Government Performance and Results Act (GPRA). The study recommended that NASA apply relative measurements of reliability within the earth- and space-science portfolios to monitor process improvement. NASA could also use these measures to communicate overall program risk to policy offices and to distribute reserves within its programs.

The study also recommended a formal review process for the ITP. The review should involve senior technologists as peers. It should include individuals who use space technology—mission scientists, who rely on technology to meet future requirements, and spacecraft designers, who must integrate new systems. The resulting user-peer review process should also involve external, unbiased experts to assess the merits of the agency's progress on these programs.

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

IV. CRITICAL INFRASTRUCTURE AND TECHNOLOGY

SECURITY OF THE INFORMATION INFRASTRUCTURE

The growing reliance of U.S. industry on information networks has raised security concerns about the vulnerability of that infrastructure to attack and disruption by outside threats. This study examined the vulnerability of the U.S. information infrastructure (see research highlight).

CYBERPAYMENT TECHNOLOGIES AND MONEY LAUNDERING

Innovations in Internet commerce and electronic transactions have begun to challenge existing regulatory and law-enforcement frameworks. Whereas in the past money laundering required the involvement of intermediaries, each of which left evidence of its activities, in the future the use of cyberpayment systems for electronic commerce may reduce the information available to government authorities for investigating money laundering. The potential exploitation of Internet commerce by criminals or terrorists is a critical new challenge facing law-enforcement and financial regulators as a result of the information revolution. This emerging situation demands that the law enforcement and financial communities improve their understanding of the potential vulnerabilities of cyberpayment systems, identify potential countermeasures that can be deployed to make such systems more secure, and anticipate the broader implications of cyberpayment schemes for the future of monetary systems.

The goal of this effort is to design and implement a policy exercise that will serve to

- raise general awareness regarding the potential adverse impact of emerging cyberpayment technologies
- educate exercise participants across federal agencies and the private sector on the characteristics of those technologies
- explore avenues for potential criminal applications and identify associated vulnerabilities
- generate illustrative response strategies for dealing with those vulnerabilities
- consider legal, regulatory, and educational plans for implementing these strategies.

RESEARCH HIGHLIGHT

PROTECTING THE NATIONAL INFORMATION INFRASTRUCTURE

The United States is not in imminent danger of massive disruption through infrastructure cyber-attacks. In part, this stems from the resilience the country has developed from having to deal with natural disasters and man-caused events of various kinds and

magnitudes; in part, from the responses of organizations to insulate themselves against anything that causes operational intrusions or upsets.

The country can readily withstand some level of attack and recover—and can even enhance its ability to do so by strengthening and/or expanding the mechanisms now in place to handle what are commonly called disaster areas or business disruptions. It follows that, for extreme events, the national preparation that has been completed for lesser ones will provide an enhanced basis for response to a "big one." For small attacks especially and for some moderate and/or coordinated attacks, the country can make do without—or with impaired—sectors of the normal infrastructure for limited periods of time; but with such consequences as reduced efficiency, inconvenience to the citizenry, loss of living affluence, and disruption of services.

If infrastructure attacks and intrusions are extensive enough to disrupt or destroy the functioning of very large geographical areas, or bring down a major industry, or if several kinds of attacks occur in a seemingly coordinated pattern, then the country cannot expect to sustain "business as usual." In fact, we may have to deliberately stand down or limit some aspects of normal life on a regional or national basis.

Even though the country is not in imminent danger of major cyberspace attack, we should not be complacent about the possibility that our national judgment is wrong or our intelligence insight incomplete. Intentional infrastructure cyber-attacks are technically feasible; it is the probability of their happening that is uncertain. The United States must do a substantial amount of preparatory work to develop an accurate portrayal of national status and risk, level of preparedness, and a realistic estimate of threat.

No comprehensive survey has yet been made of infrastructure vulnerabilities to cyber-attacks or of the resilience of the country to withstand them. Resilience can surely be enhanced, but a study of the present status is required before actions can be recommended. A status baseline is essential; e.g., preparedness planning, sources of and status of resilience, industry vulnerabilities, present sources of early warning.

We need to establish what the engineering community would call the "noise level" in the infrastructure—namely, the day-to-day abnormal or accidental events that occur as a matter of routine operation.

Physical attack is a high-probability risk throughout the infrastructure. The United States government and the private sector must give it attention. Intelligence, early warning, and data sharing are collectively an early order of business.

Energy supplies, telecommunications, and computer-based systems share an inescapable position of centrality in the area of infrastructure, and are thus of first priority for attention and remedial actions.

- Without an ongoing supply of energy—electrical and/or petroleum based—the

infrastructure will wind down to a state of quiescence over a few days or a few weeks.

- The public switched network (i.e., the national telephone system) is a concern because it provides the bulk of connectivity among computer systems, people, organizations, and functional entities. It is the backbone of interpersonal and organizational behavior.
- The federal information infrastructure is considered to be weakly postured on computer and network security. Agencies must be motivated—or directed—to respond, and their progress monitored.
- There are specific R&D "cyber-issues" relevant to protecting critical infrastructures, particularly with respect to the computer system/telecommunication/information infrastructure. The research community must become aware of them, and be motivated to respond.

Immediate actions include improving the information security posture not only in government but throughout the private sector. Physical security needs prompt examination and, as required, attention. Near-term actions include analytic studies to establish such infrastructure features as source of resilience and characterization of normalcy (i.e., establishing the noise level), and to specify R&D requirements. Medium-term actions include establishment of a warning mechanism and a supporting coordination center. For some of these steps, White House–sponsored conferences might be an appropriate and useful mechanism, but any mechanism available to the country should also be exploited.

Publication: Willis Ware, *The Cyber-Posture of the National Information Infrastructure*, MR-976-OSTP, 1998.

V. TECHNOLOGY IN EDUCATION AND TRAINING

ANALYSIS IN SUPPORT OF THE CHILDREN'S INITIATIVE

As part of the Children's Initiative to improve the quality of life for American children, the NSTC asked RAND to analyze the scope and composition of federal R&D related to children's development and welfare (see research highlight).

LEARNING-TECHNOLOGY R&D PROGRAMS IN FEDERAL AGENCIES

As background, RAND identified the principal learning technology R&D efforts in three federal departments and agencies: The Department of Defense, National Science Foundation, and the Department of Education. The study found that the diverse missions, perspectives, and cultures of the different agencies make it difficult to create a coordinated learning technologies R&D agenda. DoD's fundamental concern is improving the quality and efficiency of its own operations; in contrast to the operational mission of DoD, NSF is charged with the broad advancement of scientific education and technology. At the Department of Education, R&D related to learning technologies is conducted in a complex and continually changing political and organizational environment.

The study also found that

- Agency and departmental mission emphases differ in their attention to education content areas. There was little emphasis on areas outside science and math.
- Formal evaluation of projects and programs is comparatively limited and traditional evaluation paradigms need to be reexamined.
- Program planning gives uneven attention to practitioner and commercial activities that have the major influence on actual applications in schools and workplaces.

The research suggested that the interagency working group tasked with addressing the problem should consider establishing a nonprofit National Learning Technologies Institute to facilitate the planning, evaluation, and dissemination of federal learning technologies programs.

IMPLEMENTING EXECUTIVE ORDER ON SURPLUS FEDERAL COMPUTERS

In 1996, President Clinton issued an executive order requiring federal agencies to make surplus computers available to schools and nonprofit organizations. Subsequently, CTI was asked to study agency progress in implementing the new executive order. The project examined the potential supply of surplus government computers in relation to

school needs, assessed agencies' early experiences with the executive order, focusing on barriers to implementation, and identified lessons and "best practices" from existing government programs and successful private-sector efforts that might be applied to overcome these barriers.

The study found that most agency program leaders felt that the program was not given high priority at upper agency levels, especially since no funds were authorized for carrying out the order. Concerns also surfaced about identifying appropriate recipients, delivering equipment, and upgrading and repairing it. To address these concerns, the authors drew on the successful experiences of established federal donation programs and the private sector to make recommendations for continuing implementation. Private-sector experience suggests that use of specialized organizations to upgrade and refurbish computers can increase the number of operable and useful computers substantially. About 60 agencies have developed implementation plans, some of which build on existing programs.

ANALYSIS IN SUPPORT OF CHALLENGE GRANTS FOR TECHNOLOGY IN EDUCATION

In 1997, the National Science and Technology Council's Committee on Education and Training (CET) planned a research, development, and demonstration program called Challenge Grants for Technology in Education to advance the use of telecommunications and other technologies in support of education and training across the country. The program, to be administered by the new Interagency Learning Technology Office (ILTO), will award grants to provide seed money for implementing promising new technologies in specific learning communities. CTI will provide analytic support for ILTO in seeing that evaluations of the various technologies' educational value are carried out in a timely and effective manner. This project extends work initiated under NSTC's Task Order 14 on the role of technology in education. CTI will continue to work closely with OSTP and NSTC/CET to ensure that the results of this task inform the continuing development of federal policy for education and training technology.

The project conducted the following specific activities:

- Developed guidance and assistance documents for the project teams selected to receive Challenge Grant awards, to suggest useful and appropriate approaches to evaluation of their projects.
- Helped project teams plan and organize their evaluation efforts, via workshops and other assistance.
- Assisted ILTO in developing performance indicators for the Challenge Grant program as a whole.
- Prepared papers and presentations to guide and assist the evaluators of Challenge Grant projects and the ILTO staff.

At the Department of Education's request, RAND prepared a sourcebook to help project managers and evaluators design an evaluation that would (1) delineate and communicate expectations and key milestones, (2) provide regular feedback to project leaders and other participants, (3) document project outcomes and lessons learned, and (4) provide an account to funders and stakeholders. RAND proposes that documentation of projects take the form of a Progress Portfolio.

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

RESEARCH HIGHLIGHT

ANALYSIS IN SUPPORT OF CHILDREN'S INITIATIVE

One question the Children's Initiative sought to answer was "How much does the federal government spend on research and development related to children and adolescents?" To answer this question, CTI conducted an analysis of federally supported R&D programs related to children.

CTI conducted its analysis using the RaDiUS™ database. A number of agencies also provided information directly to CTI to supplement the RaDiUS™ data. The CTI analysis estimated the size and composition of the federal portfolio; it is not a comprehensive, in-depth examination of each federal R&D project related to child and adolescent development.

CTI found that, in fiscal 1995, the federal government spent an estimated $2 billion on R&D directly related to children and youth. These funds were distributed among 12 federal departments, including eight agencies within the U.S. Department of Health and Human Services (HHS) and 21 funding components within the National Institutes of Health (NIH) and three independent federal agencies. The National Institute of Child Health and Human Development (NICHD), the National Institute of Mental Health (NIMH), and the Department of Education account for about half of the research.

There are several ways to put in perspective the estimated $2 billion federal R&D investment in children and youth. One way is to compare this investment to the total federal R&D budget, which includes research on defense, energy, health and other topics. Such a comparison shows that federal R&D on children represents less than three percent of the total federal research investment of $71 billion, and about six percent of the $33 billion nondefense R&D budget.

The research showed that the federal investment in R&D affecting children is relatively small compared to that in other areas. The share of total national R&D directed toward children is less than 1.2 percent. This is true despite the fact that, unlike in other areas of research, the federal

government bears almost total responsibility for such R&D. For instance, the private sector provides over 50 percent of health and energy R&D funding and over 90 percent of transportation R&D. In contrast, the federal government provides approximately 90 percent of children's R&D.

A second way to consider the investment in R&D for children is as a proportion of total expenditures on children. The U.S. total investment in R&D is between 2 and 3 percent of national expenditures (Gross Domestic Product, or GDP). In the areas of health, energy, and transportation, the United States invests between 2 and 3 percent of expenditures in R&D. This R&D commitment is directed toward making the expenditures in each area more effective and efficient.

In contrast to the 2–3 percent commitment in other areas, less than three-tenths of a percent of the expenditures on children is spent for R&D on children (see Figure 4). Total government expenditures for children and youth in FY1995 were an estimated $555 billion, almost two-thirds of which was devoted to K–16 education. Most of the remaining funds were allocated for social welfare (including Aid to Families with Dependent Children (AFDC); Medicaid; Head Start; the Women, Infants, and Children supplemental food program (WIC); and Food Stamps), criminal justice (including police, courts, and prison expenditures), health care, and other programmatic expenses. Private-sector expenditures for children are far larger than public-sector expenditures, so our total R&D commitment to children of $2 billion to $2.4 billion is certainly less than three-tenths of a percent of public and private expenditures for children.

Given these comparisons, an obvious question is whether the nation's investment related to child and adolescent R&D is

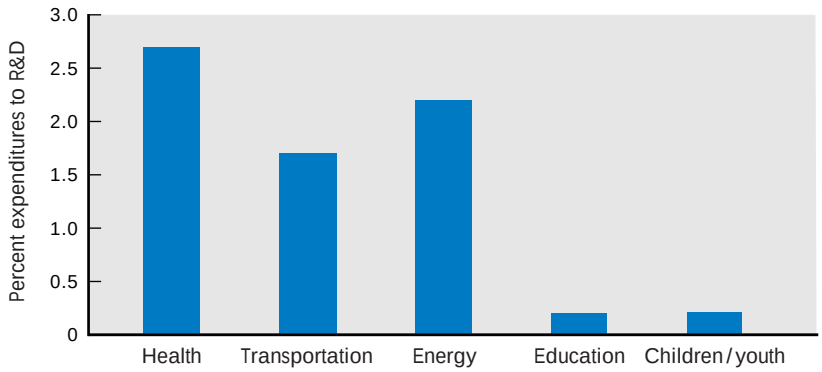

Figure 4—Share of Spending Devoted to R&D Is Smaller for Children and Youth Than for Other Areas

consistent with our research investments to solve other social, economic, energy, transportation, and health problems. The lack of dramatic progress on some youth-related problems may stem from having limited R&D funding that must be spread across the spectrum of developmental problems arising during the first 20 years of life.

The U.S. research investment in children needs to address developmental issues (social, emotional, cognitive, and health) from before birth to age 21 and also a wide range of social issues (such as education, social services, and delinquency). In addition, such research should seek not only to address issues and problems that arise during childhood but also to uncover the origins of health conditions that are manifested later in life but have their genesis and best hope of prevention in childhood.

This analysis was presented in a report published by the National Science and Technology Council Committee on Fundamental Science Committee on Health, Safety, and Food: *Investing in Our Children: A National Research Initiative for America's Children for the 21st Century*. The document is available on OSTP's website at http://www.whitehouse.gov/WH/EOP/OSTP/Children/.

VI. FEDERAL R&D PORTFOLIO

COOPERATIVE R&D IN REMOTE SATELLITE SENSING

A growing area of international cooperation is the use of remote satellites to obtain data about the earth and its atmosphere. This study examined the nature and extent of U.S. cooperative activities in this area (see research highlight).

ECONOMIC CONSEQUENCES OF U.S. INTERNATIONAL TECHNOLOGY-TRANSFER POLICIES

The United States is a net exporter of technology and technical knowledge. There are concerns that this outflow of technology means that U.S. taxpayers in effect subsidize foreign R&D. This study examined U.S. policies for monitoring and restricting the flow of government-developed technology and attempted to estimate the economic consequences of technology transfers overseas.

The study found that it would be impractical to institute a governmentwide 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 research and development. Finally, government agencies do not see international technology transfer issues as central to their missions and are likely to consider new requirements to be 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 capture the benefits of certain technological innovations.

ANALYTIC SUPPORT FOR FOURTH NATIONAL CRITICAL TECHNOLOGY PANEL (NCTP) REPORT

Critical technologies assessment can serve several purposes. In the United States, the purpose is to measure the health of this area of public concern, to highlight what appropriate actions government needs to take to fulfill its constitutional responsibility for national defense and public welfare, and to do so through a public and inclusive process.

The National Critical Technologies Report (NCTR) process has been elaborated with each successive two-year iteration. The Second NCTR addressed the larger issue of the process itself. It recommended that the NCTRs be used to better understand how technology is linked to economic well-being.

The Third NCTR laid a foundation by providing a detailed discussion, based on expert opinion, of the technologies deemed most important for the future.

The Fourth NCTR will continue the work of the previous NCTPs and will primarily address problems of substance and procedure that have arisen in all previous efforts. On the substantive side, it will seek to understand what is meant by a "critical technology." On the procedural side, it will attempt to gain a new perspective by looking as much as possible from the industry viewpoint.

The analysis is engaging the following three questions with selected firms:

1. What makes technologies critical? For whom are they critical and for what purpose are they held to be critical?
2. Among the list of emerging technologies and according to the criteria developed by the National Critical Technologies Panel, what are the technologies that appear to industry to most match these criteria?
3. What is the appropriate public role in sustaining the environment in which these technologies may be developed and utilized?

The supporting analysis will be based on in-depth interviews with industry personnel from larger firms. These interviews will form the basis for a report to the NCTP that will seek roughly equal representation from industrial categories that track into the technology areas identified by the Third NCTR, with the addition of a consideration of the services sector. Primary attention will be directed toward industries heavily engaged in materials processing, information technology, and, manufacturing technology. The Fourth NCTP views these as the cutting edge of the U.S. technological base. The report is expected to be published in Fall, 1998.

RESEARCH HIGHLIGHT

COOPERATIVE R&D IN REMOTE SATELLITE SENSING

Because satellite observations of the earth provide valuable information regarding the behavior of the planet, many other nations are seeking earth observation information and are developing sophisticated satellites and earth-based capabilities in this area.

These developments represent opportunities for partnership to better serve the international community. Interest in international cooperation in satellite observation research continues to grow, with proposals arising in bilateral and regional forums. To ensure that U.S. participation in these international arrangements is conducted in the most effective manner, timely and strategic coordination is needed. This study will help shed light on the extent of coordination efforts and opportunities for improvement.

The goal of this study was to catalog and assess international R&D agreements related to earth observation satellite monitoring and

exchange and management of earth observation data in which the U.S. is engaged. The study addresses two questions:

1. What is the full set of international agreements addressing satellite observations of the earth and the exchange and management of earth observation data in which the U.S. is involved?
2. How is U.S. participation in these agreements coordinated, and are the mechanisms for coordination effective?

The study found that as of November 1997, a total of 490 international science and technology agreements (ISTAs) were in force to support aspects of unclassified U.S. international cooperation in remote sensing and earth observation. These agreements have been signed with 76 countries and six multinational organizations and cover the operations of 32 active satellites conducting remote sensing as of the end of 1997.

Five agencies account for more than 90 percent of the remote-sensing ISTAs identified for this project: in the Department of Commerce, the National Oceanic and Atmospheric Administration (NOAA); in the Department of Defense (DoD), the U.S. Air Force and Defense Mapping Agency; in the Department of the Interior, the U.S. Geological Survey (USGS); NASA; and in the U.S. Department of Agriculture, the Forest Service. NOAA, with 285 ISTAs, leads other government agencies in the total number of agreements in place to sponsor

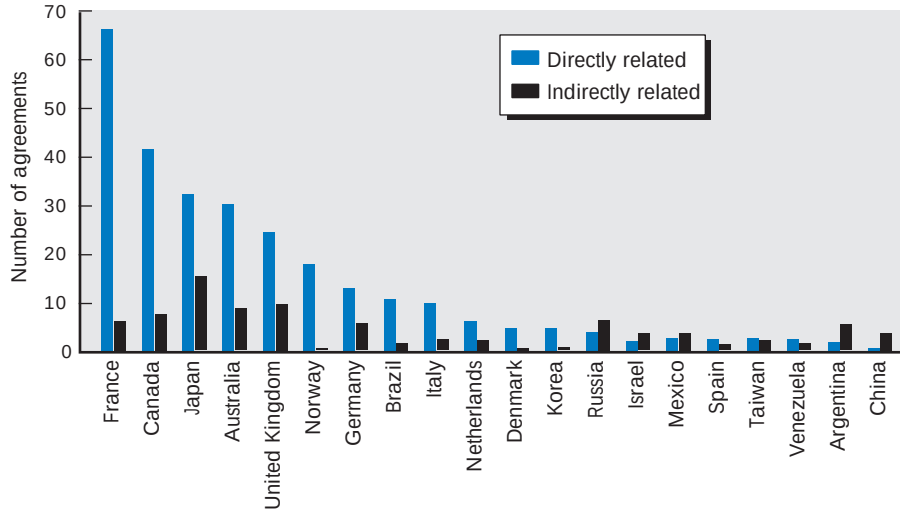

Figure 5—Principal U.S. Partners in International S&T Agreements on Remote Sensing

cooperative activities, followed by NASA with 99 and DoD with 56.

Fewer than 10 percent of these agreements have been approved through a formal interagency process. However, U.S. government agency officials actively seek informal interagency coordination for international cooperative agreements. This coordination takes place between government agency officials, who report keeping active contact with their counterparts in other agencies.

Current governmentwide policy covering negotiating and signing international agreements allows the agencies considerable latitude to determine when to establish formal cooperative relationships with other countries. The current mix of formal and informal coordination works well, according to agency officials. Nevertheless, the lack of a clear policy on when to enter into an agreement and at what level of formality to establish relations results in inconsistency across the agencies about how, when, and why to agree to cooperate. Moreover, lack of a central location to collect these agreements and provide information about them leads to some duplication of effort among agencies. One government official suggested that the current process of informal coordination has grown up largely because of the cumbersome nature of the formal interagency process, which takes months to complete and often delays important international cooperative activities.

The research identified three possible policy actions. The first action would be to rationalize the terms of and descriptions for international agreements across agencies. Each agency currently uses its own names for agreements, making it difficult to compare the nature of U.S. activities across agencies. A second action would be to create a central clearinghouse for information on agreements, perhaps using the World Wide Web to store and obtain information on government agreements. Third, streamlining the formal interagency (Circular 175) process, possibly using new information tools such as electronic file transfer, may increase the frequency with which this process is used.

Publications: Caroline S. Wagner, *International Cooperation in Research and Development: An Inventory of U.S. Government Spending and a Framework for Measuring Benefits*, MR-900-OSTP, 1997; and *International Agreements on Cooperation in Remote Sensing and Earth Observation*, MR-972-OSTP, 1997.

VII. SPECIAL PROJECTS AND OUTREACH

As part of its core mission, CTI conducts additional activities beyond its policy analysis. These include a variety of special projects categorized as "core" research efforts, including overseeing the RaDiUS™ data system and a range of outreach activities.

RaDiUS DATA SYSTEM SUBSCRIPTIONS

RaDiUS is a data system developed by RAND that contains descriptions and expenditures of all U.S. federally funded research and development conducted since 1995. RaDiUS has been used to support several research projects at RAND and will continue to be used to support several Presidential and NSTC initiatives.

A special subset of NSF's five-year review of CTI examined the issue of sharing RaDiUS costs through the purchase of subscriptions by federal user agencies. These RaDiUS subscriptions would provide each federal agency with better access to its and other agencies' R&D records to improve the coordination and management of the federal R&D enterprise. All subscriptions will be governed by and accounted through a task order under the CTI FFDRC contract with NSF. Each subscription, however, will be individually funded through a purchase order sent directly to RAND from subscribers within the agencies.

The NSF Comprehensive Review Panel recommended that NSF commission an advisory panel of government and outside experts to evaluate RAND's RaDiUS data system. The RaDiUS Review Panel's report included the following recommendations for short-term and long-term actions:

- To ensure RaDiUS's immediate and short-term viability, the federal government should enter into a three-year agreement with RAND. In principle, the agreement should provide the following:
  - Funds raised by making RaDiUS available to federal agencies and government contractors (i.e., subscription fees) should be used to offset the cost of maintaining the system.
  - Funds raised in excess of the amount needed to maintain RaDiUS should be provided to RAND to offset its share of the original development costs.
  - To the extent that the funds raised by subscription fees are inadequate to sustain RaDiUS, the government (NSF) should agree to underwrite this cost for a period of three years.
- OSTP should designate NSF as the lead federal agency for RaDiUS's operation. OSTP and NSF should formulate a joint working plan for the continued operation

of RaDiUS as a support mechanism for OSTP and NSTC.

- Working with OSTP, NSF should develop working arrangements with participating federal agencies to develop standards for the internal data systems that comprise RaDiUS. NSF should also establish a committee of RaDiUS users and potential users in participating federal agencies to advise NSF and OSTP on RaDiUS—including data needs, system enhancements, resource requirements, and user access principles.
- Within three years, NSF should issue a request for proposal for the multiyear operation of the RaDiUS system.

Throughout 1997, RAND continued its market evaluation of RaDiUS and its efforts to develop a user base capable of supporting the system. NSF will consider the possibility of government support for the system in the context of its Review Panel recommendations.

VIII. INTERNS AND AAAS FELLOWS

INTERNS

CTI hosts interns from across the country, typically over the summer as part of its core research efforts. The objective of the internship program is to provide analytic experience to participants, provide them with a window on the science and technology policy formulation process, and give CTI first-hand experience with students from the science and technology programs conducted at a broad range of academic institutions. The interns participate as project team members on CTI tasks, typically fulfilling the role of research assistant to senior staff members.

The number of interns hosted each summer is based on a number of factors. CTI obtains interns principally through the American Association for the Advancement of Science (AAAS) Science and Technology Interns Program, through which CTI selects up to two interns each year. The AAAS program provides the basis for CTI's selection process for interns for other programs, including the RAND Summer Interns Program, the MIT Technology and Public Policy Program, and the George Washington University Science and Technology Policy Program. CTI typically hosts one to two additional interns from these programs, depending on the requirements of the student's program, funding arrangements, and the ability of project leaders to provide a positive educational experience without compromising their responsibilities under the research plan.

AAAS FELLOWS

CTI's legislative charter and contractual obligations call for it to consult widely with representatives from private industry and to incorporate information and perspectives derived from such consultations in its work. One of the ways that CTI fulfills this aspect of its mission is through a fellowship program conducted through the auspices of the AAAS. In this program, CTI hosts one or more research fellows each year as part of CTI's core research. This enables senior scientists and technology experts from private industry to spend a year with CTI and participate in CTI research. The program's benefits are numerous—CTI learns about industry's perspective on key science and technology issues and is able to incorporate these considerations into its analysis and reports to OSTP; the experience and skills of senior staff are available at a fraction of their normal cost due to cost-sharing arrangements with AAAS and each Fellow's sponsoring firm; and the fellows in turn learn about the public policy perspective of CTI's sponsors and the policy formulation process.

Dr. Elisa Eiseman, the CTI-AAAS Fellow during 1997, is supporting the President's National Bioethics Advisory Council (NBAC). One of her projects focuses on the

issue of cloning. A paper on stored tissue samples is in peer review within RAND. Dr. Eiseman will publish the report on stored tissue samples, and she will continue to support the NBAC with research and analysis as requested. The CTI Director will meet with AAAS staff to discuss candidates for the 1998 AAAS-CTI Fellow (due to commence in September 1998).

SEMINARS

During 1997, CTI conducted a series of seminars on important technology issues. Each seminar featured a distinguished speaker and prominent discussants and was open to the public.

Antimatter. For each fundamental particle, there exists an antiparticle with the same inertial mass, the same intrinsic lifetime, and an opposite electrical charge. In the past two years, experimental physicists have combined anti-electrons and anti-protons into actual anti-atoms of hydrogen. In principle, this opens the possibility of creating macroscopic amounts of condensed anti-hydrogen. In the next century, this could allow applications ranging from medical imaging to space travel, depending on the amount that becomes available. Can antimatter move off the pages of science fiction and into practice?

Biosensors. Combining biological agents with high-speed electronics has long been discussed, but is only beginning to be realized. Biosensors are moving from the proof-of-concept stage to field testing and commercialization in the United States, Europe, and Japan. They have potential for continuous and in-situ applications in such fields as medical diagnostics, genetics, and environmental monitoring. For example, emerging DNA microchip technology is being designed to analyze gene expression patterns, carry out genome-wide mapping, and detect genetic mutations. Biosensors such as nerve cells grown on a microprocessor can provide electrical signals in response to stimuli such as the presence of toxins in the environment. These technologies are creating strategic, innovative links between electronic engineering and biological sciences with far-ranging implications for both fields.

Nanotechnology Applications in a Space-Based Environment (co-sponsored by The National Space Society). Since the 1993 CTI seminar on nanotechnology, the field has developed quickly enough to warrant a second look at this technology. It has gone from a "what if" to a "how" mode, with engineers exploring the use of scanning tunneling microscopes and other production tools to assemble complex structures from the atomic level on up—molecule by molecule, as nature does. As an engineering discipline, molecular nanotechnology promises revolutionary advances not only in manufactured products, but in the processes used to make them. Initial applications may include space-based machining and electronic and quantum computing. This seminar examined the feasibility of these developments over the next 20 years.

Quantum Computing (co-sponsored by Texas Instruments). Computer hardware performance is bumping up against natural limits imposed by the laws of physics. Quantum physics offers a tantalizing possibility: the construction of qualitatively new types of logic gates and absolutely secure cryptosystems. In theory, quantum computers can conduct massively parallel computation—not by having many processors working in parallel but by having a quantum processor performing a single command operating on a coherent superposition of many different numbers simultaneously. The implications for the future of computing are astounding and revolutionary. The recent and potential developments were explored in this seminar.

Solar Energy from Satellites (co-sponsored by NASA). Solar-powered, space-based satellites may eventually be used to beam energy to earth. The solar energy collected by a solar-powered satellite would be converted into electricity, then into microwaves. The microwaves could be beamed to the Earth's surface, where they would be received and converted back into electricity by a large array of devices known as a rectifying antenna, or "rectenna." This concept is being tested now and, if proven efficient and effective, could change the way we think about energy production and use. This seminar examined current developments and the feasibility of large-scale investment in this technology.

IX. CTI PUBLICATIONS

Note: All MRs and RBs are available on the CTI Web site in HTML or PDF format at http://www.rand.org/centers/stpi/.

HEALTH AND THE ENVIRONMENT

Reports

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

Linking Sustainable Community Activities to Pollution Prevention: A Sourcebook, Beth Lachman, MR-855-OSTP, 1997. For a summary of this research, see RB-1502, "On Common Ground: Sustainable Community Activities and Pollution Prevention," 1997.

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

Other Publications

Technology for a Sustainable Future-—Ideas: A Summary of Workshop Discussions, Beth Lachman, Robert Lempert, Susan Resetar, Thomas Anderson, RP-417, 1994. Reprinted from White House Conference on Environmental Technology, 1995.

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

"National Environmental Technology Strategy: Residential Construction Workshop," October 1994, Thomas L. Anderson, Beth E. Lachman, P-7965, 1996.

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

SPACE AND TRANSPORTATION

Reports

The Global Positioning System: Assessing National Policies, Scott Pace et al., MR-614-OSTP, 1995. For a summary of this research, "A Policy Direction for the Global Positioning System, Balancing National Security and Commercial Interests," RB-1501, 1995.

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

Other Publications

"The Regulation of Commercial Remote Sensing Systems," Scott Pace, CT-112, 1994. Congressional testimony.

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

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

CRITICAL INFRASTRUCTURE AND INFORMATION TECHNOLOGY

Reports

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

TECHNOLOGY IN EDUCATION AND TRAINING

Reports

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

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