Executive Summary

More efficient use of energy, more efficient medical treatments that cost less and cause less pain, the capacity to process growing volumes of data, better vehicles, and improved position in the highly competitive international electronics market—these are among the many significant achievements of projects supported by the Advanced Technology Program (ATP) over its first decade. Results from the first 50 completed projects are strong for ATP, with estimated benefits far outweighing the entire cost of ATP to date.

The First 50 Projects

Policymakers, program administrators, business managers, and others in this country and abroad have eagerly awaited a comprehensive look at results from ATP-funded research projects. This report provides at least partial answers by assessing the first 50 completed projects—approximately 10 percent of the projects funded by the ATP from 1990 through 2000. The performance metrics show how each of the 50 projects performed in terms of new technical knowledge created and disseminated, direct commercialization of new technologies, and overall project effectiveness.

Project Characteristics

The majority of the first 50 completed projects are single-applicant projects led by small businesses. Although only 16 percent are joint ventures, 84 percent involved collaborative relationships. Nearly half had close R&D ties with universities, and more than half formed collaborative arrangements with others to pursue commercialization.

ATP's designated technology area *Electronics/ Computer Hardware/Communications* comprised the largest group of projects, followed by *Manufacturing*, *Biotechnology and Advanced Materials/Chemicals*, and, last, *Information Technology*.

The ATP spent an average of $1.5 million per single-applicant project and an average of $4.9 million per joint-venture project. Across the 50 projects, the average total cost (ATP plus industry) per project was $4.2 million, and the median project length was three years. Together, ATP and industry spent a total of $208 million on the 50 projects, with ATP and industry sharing total research costs roughly equally.

ATP's Mission and Operations

The National Institute of Standards and Technology (NIST), a part of the Department of Commerce's Technology Administration, administers ATP. The ATP and industry share research costs for projects characterized by ambitious scientific and technological goals, and by a strong potential to improve the competitiveness of U.S. businesses and offer substantial economic return to the United States. The ATP seeks to accelerate the development and application of enabling technologies whose benefits will extend well beyond the direct benefits to the ATP award recipients. The focus is on collaborative, multidisciplinary research and on civilian technologies that appear likely to be commercialized in the marketplace with private sector funding once the high technical risks are reduced. The projects funded are selected in rigorous competitions on the basis of their technical and economic merit, as determined by peer review.

Since 1990, ATP has committed funding of $1.6 billion in research costs for 522 projects, with companies contributing a similar amount in matching funds for the research, and much more in the post-project periods for follow-on commercialization. More than 1,000 companies, universities, and nonprofit laboratories lead the projects or participate as members of research joint ventures. More than 1,000 additional organizations are involved as subcontractors and informal collaborators.

Study Scope, Approach, and Organization

This report comprises one element of ATP's evaluation program, providing a systematic and comprehensive look at a large group of ATP projects, and shedding light on the performance of the program at large.

At the report's core are 50 mini-case studies covering the first-completed projects and investigating the performance of the projects several years after completion.

Chapter 1, an overview, provides aggregate descriptive statistics, and then presents aggregate output statistics—first, for knowledge creation/dissemination, and, second, for progress toward commercial goals. It then uses all of the outputs to construct a composite performance score to indicate overall project effectiveness. The result is a four-star system of ratings, with scores ranging from zero to four stars.

For a group of top-rated, four-star projects, the chapter examines estimates of partial net benefits and considers their implications for the overall success of ATP to date. It also provides summary examples of strong three-star projects.

Because technology development and commercialization take time and are characterized by unexpected breakthroughs and failures, future updates of these projects may alter the findings reported here.

Overall Project Performance

As expected with projects that tackle difficult research problems, not all of the projects are equally successful. Sixteen percent of the projects are top-rated in terms of overall project performance. Twenty-four percent are in the bottom group in terms of project performance. Sixty percent make up the middle group.

The top performing projects not only solved challenging and significant technical problems, but also made the new technical knowledge available to others, and directly used that knowledge to accelerate commercial use of the technology—three dimensions of performance that figure prominently in achieving the long-run success of the ATP. Among this group, half of the top performing projects received awards for their technical accomplishments from outside organizations, and more than half of the single-company project leaders received outside recognition for their business accomplishments. All of the top-rated projects forged collaborative relationships, and all attracted private capital for their follow-on commercialization efforts. Among the single-company projects in the group, all the companies expanded their employment substantially. All had a very strong outlook for continued progress, and, in fact, have continued to make strong progress.

The lowest scoring projects were not without accomplishments. Most performed research and produced patents or technical publications, or gave presentations. But none won awards or showed sustained direct progress toward commercialization, and the outlook for direct commercial action of the award recipients was poor or uncertain at best.

The large mid-scoring group of projects had solid—and, in some cases, outstanding— technical accomplishments, and, in some cases, made substantial progress toward commercialization. In other cases, the projects were strong technically, but showed little follow-on commercial progress. In a few cases, the projects produced a technology with commercial strength but did little to disseminate knowledge to others—a public-interest goal of the program. In yet other cases, there was moderate progress in creating and disseminating knowledge and moderate progress toward commercial goals. This middle group, although not featured in the discussion of net benefits in this report, will likely yield substantial net benefits overall.

From a portfolio perspective, the results look strong for ATP: the estimated net benefits attributed to the program from the top-performing projects alone far exceed the entire cost of ATP to date, suggesting that the program is on track to produce a high return for the nation.

In addition, there is evidence that the benefits are extending well beyond those enjoyed by the award recipients. For example, when patients receive superior medical treatments at lower cost, there are spillover benefits. When consumers buy high quality products and do not pay the full value for the additional benefits they receive, there are spillover benefits. When other companies increase their productivity or value added by using ATP-funded technologies, there are spillover benefits. When others acquire and use productively the knowledge from project findings, there are spillover benefits. Several examples illustrate technology developments and commercial progress of this first group of projects. (See box)

Peer Recognition of Technical Achievements

The knowledge created by each project is the source of its future economic benefit, both for the innovator and for others who acquire the knowledge. Knowledge created by the 50 projects ranges from mathematical algorithms underlying new software tools, to the science of growing human tissue, to new techniques for fabricating high-temperature superconducting devices. Recognition of technical achievements by outside organizations, including trade associations, foundations, and technical journals, indicates

PROJECT EXAMPLES

The National Center of Manufacturing Sciences (NCMS) Ann Arbor, Michigan, led a joint venture to achieve dramatic technical advances in manufacturing printed wiring boards (PWBs). As a foundational component to any larger electronics assembly, PWBs are essential to many other technologies, and are used in the manufacture of products ranging from computers to toys to vehicles. And, advances in PWBs improve the position of U.S. companies in the very competitive world electronics market.

The research team made advances in materials, soldering, imaging, and chemical processes. A new single-ply fiberglass PWB, which allows substantial cost savings, has become the industry standard. New process methods increase dramatically the yield of boards without flaws. A new surface finish protects the board in multiple soldering applications. A new process for attaching thin copper plating to fiberglass reduces processing time and materials cost. A novel interconnect structure has the potential to revolutionize the fabrication of PWBs by enabling much higher wiring density. And, according to an in-depth economic study, because the research effort was collaborative, the new capabilities were developed at a research cost-savings of at least $35.5 million.

The various joint-venture participants and their licensees have successfully commercialized component technologies arising from the project, resulting in substantial productivity improvements. Award-winning papers, patents, and new process technology helped convey the information to the hundreds of small companies that make up most of the industry. The president of NCMS credited the project with literally saving what was then the $7 billion U.S. PWB industry—a key segment of a $20 billion domestic electronic interconnection industry employing over 200,000 people.

Engineering Animation, Inc., Ames, Iowa, developed core algorithms that enabled the creation of three-dimensional images from sets of two-dimensional cross-sectional images of human body parts, and animation for selected organs. After an initial failure to commercialize a high-cost system that incorporated the technology, the company adapted the technology for CD-ROMs and print publications in 1995, and then bundled it with medical books. The company went on to leverage its ATP-funded technology in a multiplicity of applications featuring three-dimensional animations which utilize computer visualization and computational dynamics—in sectors as diverse as medical education, entertainment, manufacturing design, transportation, and investigation of the Oklahoma City bombing.

Founded by two professors and two graduate students in 1990, the company had 20 employees at the time of its ATP award. Now its employees number approximately 1,000, and 1999 sales totaled $71 million. The company started receiving recognition from other organizations for its technical progress in 1994, while it was working on the ATP project. It also has received extensive recognition for its business achievements, including acknowledgments by *Individual Investor, Business Week,* and *Forbes ASAP* magazines as one of the best technology companies in the country.

Aastrom Biosciences, Inc., Ann Arbor, MI, received an ATP award to develop a process for growing stem cells outside of the body in 1990, when this was a new concept. Aastrom designed, constructed, and validated a desktop-size bioreactor with the capacity to produce large amounts of stem and other cells from small amounts of bone marrow and umbilical cord blood.

The journey from university research to commercializing its AastromReplicall™ System has been a long path for Aastrom—one that is still underway, despite unabated effort and strong progress. The company has extended the time for its expected commercialization date several times.

An earlier in-depth economic study estimated that the replication system, once implemented, would save approximately $134 million (in 1997 dollars) in the costs of providing bone-marrow transplants for cancer treatment, compared to the best alternative technique. The study conservatively attributed about $47 million of the cost savings to ATP. The study also identified potential benefits of pain reduction and better patient outcomes from the technology but did not quantify them.

Results from recent clinical trials point to an additional benefit—enabling cancer patients without donors to receive stem cell transplants. Aastrom's replication system can expand tiny amounts of matching cord blood into sufficient quantities for adult transplantation. According to the director of medical oncology at Hackensack University Medical Center, "these results suggest that we may have found a new treatment approach that will enable more patients to receive treatment for this very serious and often fatal disease." According to the American Cancer Society, 30,000 new cases of leukemia are expected in 2000 and approximately 20,000 people will die from the disease this year, making new, more effective treatments of great value to society.

that others see considerable value in the projects. In 1996 alone, the projects claimed the following awards:

R&D magazine–an R&D 100 award to **American Superconductor, Inc.**, in Westborough, Massachusetts, for its development of CryoSaver current leads;

Industry Week magazine–one of 25 Technology of the Year Awards to **American Superconductor, Inc.**, for applications of superconducting wire;

Industry Week magazine–one of 25 Technology of the Year Awards to **Engineering Animation, Inc.**, in Ames, Iowa, for its interactive 3D visualization products used in the manufacturing sector for product development;

Discover magazine–one of 36 finalists for Technology of the Year to **HelpMate Robotics, Inc.**, in Danbury, Connecticut, for the HelpMateRobot used in hospitals;

Microwave & RF magazine–one of the Top Products of 1996 to **Illinois Superconductor, Inc.**, in Mt. Prospect, Illinois, for cellular phone site filters and superconducting ceramics;

Computerworld magazine–finalist for the Smithsonian Innovator Medal to **Molecular Simulations, Inc.**, in San Diego, California, for advances in software to help scientists simulate and visualize complex molecules.

Dissemination of New Technical Knowledge

Dissemination of the new knowledge provides spillover benefits to other companies who, in turn, may use the knowledge to increase and broaden the national benefits from the ATP investment. Dissemination takes place in several ways. Patents, publications, and presentations provide a convenient avenue for others to acquire the knowledge. All but 1 of the 50 projects produced one or more of these outputs.

The extensive collaborative activities of the projects have provided another avenue for the spread of knowledge. Eighty-four percent of these projects entailed collaborations, including other companies, universities, national laboratories, nonprofit consortia, and other organizations and individuals.

Release of new products to the market also disseminates new technical knowledge. Others can use the products and they may also attempt to discover how the products work by observation, testing, and reverse engineering. More than 60 percent of the projects placed commercial products or processes in the marketplace, providing others with the ability to collect information about the new technologies.

Workshops, websites, and evaluation studies also facilitate information flows. The ATP has organized and sponsored numerous public workshops over the years, in which the companies have presented nonconfidential aspects of their ATP-funded research and engaged in open discussions. The ATP has also made project information available on its website (<www.atp.nist>). Evaluation reports, such as this one, are an additional source of information for the public.

Commercial Progress in Applying the New Technologies

If the new knowledge is to yield economic benefits to the nation, the award recipients, their collaborators, or the companies who acquire that knowledge must put it to use. A second focus of the study, therefore, is on the commercialization progress of the award recipients, and in some cases their direct collaborators. The study does not include commercialization activities of companies who acquire project knowledge indirectly, although these activities may be as important or more important than those of the award recipients and their collaborators.

Sixty-six percent of the 50 projects had one or more products or processes in the market when they were assessed, and another 14 percent expected to shortly. Thus, despite the difficulty of moving from the research stage to commercialization, companies in 80 percent of the projects either sold product, or used or licensed to others process improvements stemming from their research, or they were about to do so at the time they were contacted by study analysts. Whether or not widespread diffusion of a technology results from these commercial activities, it is highly significant that products and processes are actually on the market.

An indicator that a small research-oriented company is on the path toward commercialization is company growth. A recent look at *Fortune's* "Fastest Growing 100 Companies" list found 2 of the 31 then-small ATP-funded companies on the list.

Capitalized value of some of the ATP-funded companies has increased by hundreds of millions of dollars. Nearly a fifth grew in employment by more than 500 percent from the beginning of the project to several years after the project had completed, and 61 percent grew in employment by more than 100 percent. Several of the companies that were small when they received the ATP award have grown out of that size category. Nineteen of the 31 small companies at least doubled in size; 4 companies grew more than 1,000 percent.

Not all the small companies grew—a little more than one-fifth experienced no change or decreases in staff and not all kept their momentum going beyond the period of ATP funding. But, as a group, the small companies funded by ATP grew rapidly as they parlayed their new technical capabilities into business opportunities.

The study results point up the importance of the ATP's two-path approach to realizing national benefits. First, the direct commercialization effort by the award recipient provides a path for the accelerated use of the technology by U.S. companies. Second, the knowledge created by a project may disseminate to others who may use it for economic benefit whether the award recipients do or not. One path may provide an avenue for benefits when the other does not, and both paths may yield larger, accelerated benefits compared to having only a single route to impact.

What Difference Did ATP Make?

The focus of evaluation is not just on the performance of projects, but on the difference ATP made to the outcomes. The results of the more detailed studies cited here emphasize effects attributed to ATP. In addition, the mini-cases attempt to establish retrospectively the impact that the ATP had on project outcomes.

For 44 of the 50 projects responding to the question of what difference ATP made, 59 percent would not have been undertaken at all without ATP funding, and 41 percent would have begun at a later date or proceeded at a slower pace. (Personnel changes, severe company financial distress, or lack of clarity in responses to interview questions made it impossible to include 6 of the 50 projects in this tabulation.)

Other effects attributed to the ATP by the leaders of these projects include the fostering of collaborative arrangements for research and commercialization activities and the ability to raise additional capital.

Examples of company comments about the role of the ATP include:

Torrent Systems, Inc.—It is doubtful that the technology could have been successfully developed at all; venture capital funding had been sought but was unavailable.

AlliedSignal, Inc.—The company would have needed another five years to reach this stage of development.

Diamond Semiconductor Group, LLC—The company would have been unable to do the research or survive as a company; its only other alternative then was to become part of a foreign company.

Integra LifeSciences Corporation—Without ATP I don't know that we could have proceeded. We would be at least five years or more behind where we are.

Nonvolatile Electronics, Inc.—ATP funding enabled the project to be done, prevented the company from failing, and improved the company's ability to attract capital from other sources.

FSI International, Inc.—The award enabled FSI to collaborate with Massachusetts Institute of Technology researchers.

Light Age, Inc.—The visibility generated by winning the ATP award helped Light Age establish agreements with research partners and, coupled with the success of the ATP project, enabled it to secure additional funding from private investors.

Thomas Electronics, Inc.—Without the ATP award, the company would have struggled along with its conventional CRT technology and would have stood virtually no chance of competing with other display-component suppliers, all of which are foreign companies.