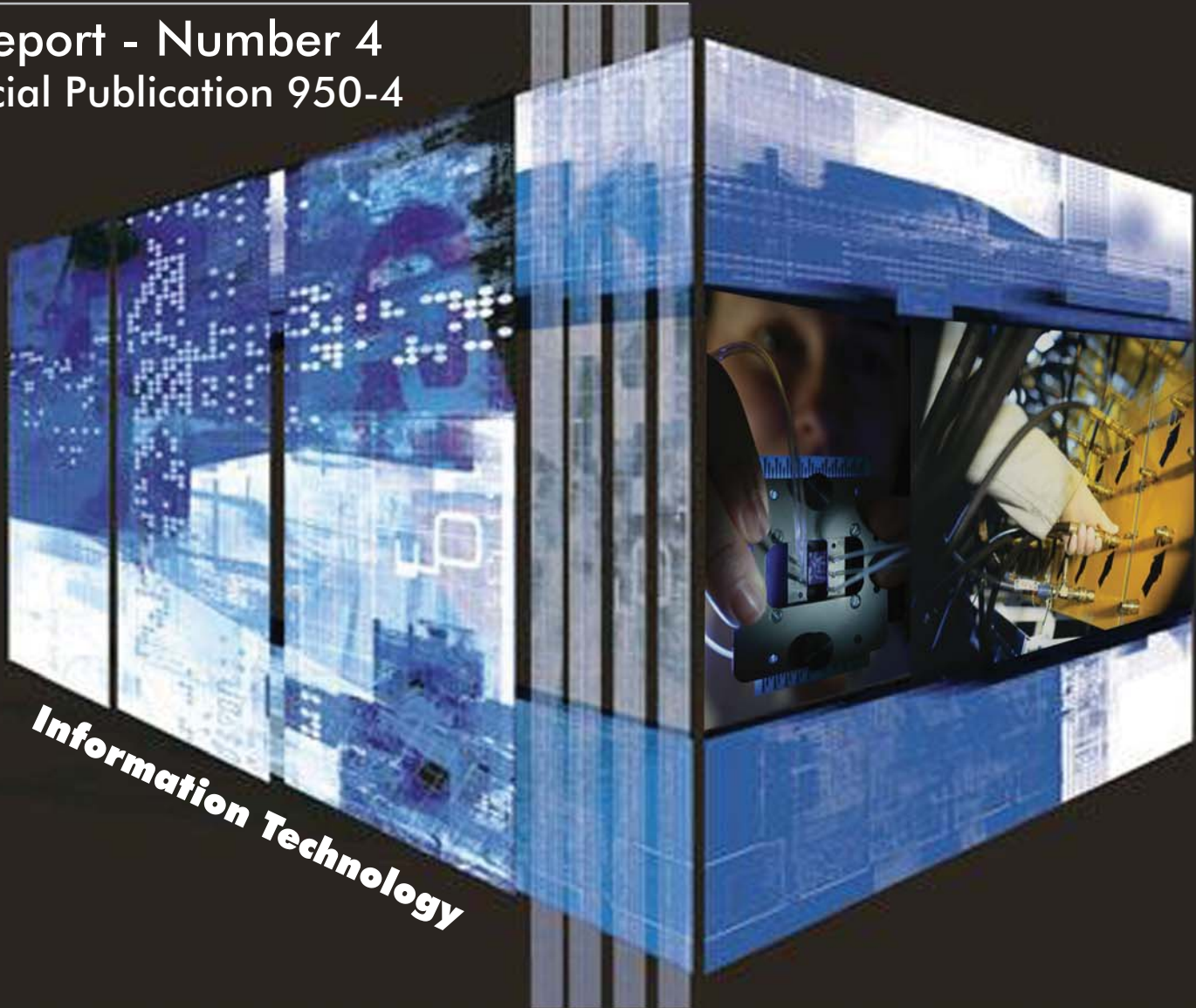![ATP ADVANCED TECHNOLOGY PROGRAM logo]

Performance of the Third 50 Completed ATP Projects

Status Report - Number 4
NIST Special Publication 950-4

Information Technology

September 2006

NIST
National Institute of Standards and Technology
Technology Administration
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ATP
ADVANCED TECHNOLOGY PROGRAM

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ACKNOWLEDGEMENTS

We are pleased to announce the completion of the next chapter in ATP's portfolio of status reports for completed projects. This compilation consists of the third batch of 50 "mini case studies" written to investigate the results and impacts of ATP's investment in innovative technologies. The goal of each status report is to provide the reader with a basic understanding of the technology, while also identifying any economic benefits that may have resulted from the ATP-funded project.

This process is a daunting one, requiring the efforts of many both inside and outside of ATP. The majority of the project was made possible by the former and current members of the status report team: Tony Colandrea, Stefanie Cox, Nashira Nicholson, Rick Rodman, Susan Stimpfle, and Virginia Wheaton. We would especially like to thank ATP Division Directors Michael Schen (Information Technology and Electronics Office) and Linda Beth Schilling (Chemistry and Life Sciences Office), and ATP Deputy Director Lorel Wisniewski, for their contributions to this project. Much appreciation also goes to the hard work of the others involved in preparing the status reports: project managers, reviewers, copy editors, and company representatives.

But these efforts aren't without rewards. As the portfolio of ATP status reports grows, we gain insight as to the role ATP plays in bridging the funding gap. We are confident this showcase of the third batch of 50 completed projects will help build on our understanding of ATP-funded innovations across many technology areas. We hope that you learn as much about the process of early-stage technology development, commercialization, and outcomes for the economy as we have in preparing these status reports.

Sincerely,

Lee Bowes, Economist
Stephanie Shipp, Director,
Economic Assessment Office
Advanced Technology Program

INTRODUCTION

Industry has proposed 6,924 projects to the ATP since 1990, of which 768, or 11 percent, have been selected by the ATP for funding. The number of participants for these funded projects totaled 1,511, with approximately an equal number of subcontractors. This study focuses on the third group of 50 projects that were completed and provides combined statistics for all 150 completed projects studied to date.

ATP: A Partnership with Industry

The ATP attracts challenging, visionary projects with the potential to develop the technological foundations of new and improved products, processes, and even industries. The ATP partners with industry on this research, fostering collaborative efforts and sharing costs to bring down high technical risks and accelerate technology development and application. These are projects that industry in many cases will not undertake without ATP support, or will not develop in a timely manner when timing is critical in the highly competitive global market. The program funds only research, not product development. The ATP is managed by the National Institute of Standards and Technology, an agency of the Commerce Department's Technology Administration.

ATP awards are made on the basis of a rigorous competitive review, which considers the scientific and technical merit of each proposal and its potential benefits to the U.S. economy. The ATP issues a proposal preparation kit that presents and explains the selection criteria to prospective applicants and provides guidance on preparing proposals.[1] U.S. businesses conceive, plan, propose, and lead the projects. Government scientists and engineers who are expert in the relevant technology fields review all proposals for their technical merit. Business, industry, and economic experts review the proposals to judge their potential to deliver broadly based economic benefits to the nation —including large benefits extending beyond the innovator (the award recipient).

The ATP delivers benefits to the nation along two pathways: 1) a direct path by which the U.S. award recipient or innovator directly pursues commercialization of the newly developed technologies; and 2) an indirect path which relies on knowledge transfer from the innovator to others who in turn may use the knowledge for economic benefit. Either path may yield spillover benefits. The ATP looks to the direct path as a way to accelerate application of the technology by U.S. businesses. It looks to the indirect path as a means of achieving additional benefits, or benefits even if the award recipient fails to continue. The ATP's two-path approach to realizing national benefits offers advantages: one path may provide an avenue for benefits when the other does not, and both paths together may yield larger, accelerated benefits as compared to having a single route to impact.

Project Evaluation

The ATP, like other federal programs, is required by law to report on its performance.[2] The ATP established its evaluation program soon after it began, even before evaluation was widely required by Congress. The Economic Assessment Office (EAO) of ATP plans and coordinates the evaluation of funded projects. It is assisted in this effort by leading university and consulting economists and others experienced in evaluation.

Performance is measured against the program's legislated mission. Emphasis is placed on attempting to measure benefits that accrue not only to the direct award recipients, but also to a broader population, i.e., spillover benefits. This emphasis reflects the fact the public funding covers part of the costs of these projects, and, therefore, a relevant question is how the broader public benefits from the expenditure.

This report constitutes one element of the EAO's multi-faceted evaluation plan: status reports. The purpose of status reports is to provide an interim assessment of the status of ATP-funded projects several years after they are completed. Although the ultimate success of the ATP depends on the long-run impacts of the entire portfolio of ATP projects, the performance-to-date of this partial portfolio provides some initial answers. This study contains an evaluation of 150 completed projects: the results of the 100 projects from the Status Report – Numbers 2 & 3, and the results and status reports of a third batch of 50 projects. These reports address the questions of what has the public investment of $321 million in the 150 projects produced several years after completion of the research, and what the outlook is for continued progress?

Study Approach

From the moment that ATP funded its first group of 11 projects in the 1990 competition, program administrators, the administration, Congress, technology policymakers, industry, and others in this country and abroad were keenly interested in the outcome. But technology development and commercialization are lengthy processes, and it takes time to produce results.

As more ATP-funded project are completed and move into the post-project period, sufficient time has elapsed for knowledge to be disseminated and progress to be made towards commercial goals. Thus, it is now possible to compile more complete aggregate portfolio statistics, and analyze these statistics with regard to implications for overall program success.

At the core of this study are 50 mini-case studies covering each of the completed projects. Each of these briefly tells the project story, recounting its goals and challenges, describing the innovators and their respective roles, and assessing progress to date and the future outlook. Photographs illustrate many of the projects.

Although the particulars vary for each project, certain types of data are systematically collected for all of them. Consistent with ATP's mission, the evaluation focuses on collecting data related to the following dimensions of performance:

- **Knowledge creation and dissemination**, which is assessed using the following criteria: recognition by other organizations of a project's technical accomplishments; numbers of patents filed and granted; citations of patents by others; publications and presentations; collaborative relationships; and knowledge embodied in and disseminated through new products and processes.

- **Commercialization progress**, which is gauged in terms of the attraction of additional capital for continued pursuit of project goals, including resources provided by collaborative partners; entry into the market with products and services; employment changes at the small companies leading projects and other indicators of their growth; awards bestowed by other organizations for business accomplishments of project leaders; and the analyst's assessment of future outlook for the technology based on all the other information.

The approach is to provide, in an overview chapter, the aggregate statistics of interest across a set of 150 projects, such as the total number of patents and the percentage of projects whose technologies have been commercialized. In addition, the aggregate statistics are combined to produce composite project metrics for overall performance. The composite performance scores allow one to see at a glance the robustness of a project's progress towards its goals. Underlying the simple scores is a wealth of data.

Sources of Information

Data for the projects were collected from many sources: ATP project records; telephone interviews with company representatives; interviews with ATP project managers; company websites; the U.S. Patent and Trademark Office; in-depth project studies conducted by other analysts; academic, trade and business literature; news reports; filings at the Securities and Exchange Commission; and business research services, such as Dun and Bradstreet, Hoover's Online, Industry Network, and CorpTech. Each one of the individual project write-ups was reviewed for accuracy by the project's lead company and ATP staff.

Study Limitations and Future Directions

Since developments continue to unfold for most of these projects, the output measures for the cases may have changed significantly since the data were collected. The cases provide a snapshot of progress several years after the completion of the ATP-funded projects.

Although undertaken at different calendar dates, the reports are written within about the same interval of time after ATP funding ended. Yet, different points in each technology's life cycle may be captured, depending on the technology area. Information technology projects, for example, may be expected to be further along than advanced materials and chemical projects. Examined at a later time, there may be less (or more) difference in the accomplishments among projects in different technology areas.

This study tracks outputs leading to knowledge dissemination but it does not assess the actual commercialization efforts by others who acquire the knowledge. The tracking of commercialization efforts is limited to the direct path of impact (i.e., commercialization by the award recipients or innovators).

"Completed" and "Terminated" Projects Defined

Projects do not necessarily finish in the order funded. For one thing, they have different lengths, ranging from approximately two years to no more than five years. For another, they are required to file a final report with the ATP and have financial and other paperwork completed before project closeout. The financial closeout is done through the National Institute for Standards and Technology (NIST) Grants Office, which notifies the ATP that it considers the project completed. This study assesses the first 150 projects the Grants Office declared "completed."

Not all ATP projects reach completion; some are stopped short and are classified as "terminated." Some of these were announced as award winners but never officially started. Other projects got off the ground but were closed for various reasons with a substantial amount of the technical work still unfinished. These terminated projects are assessed according to the principal reasons they stopped before completion. They are treated in Appendix B. While the terminated projects are generally regarded as unsuccessful, some produced potentially useful outputs.

Report Organization

The report has been divided into separate technology area "editions" in order to provide a smaller, more targeted compilation. However, the overview still provides a summary overview of the performance of the 150 completed projects as a group. It identifies some major outputs that appear useful as indicators of the degree of project success, and it uses these outputs in a prototype project performance rating system. A preview also notes some of the broad-based benefits that this portfolio of projects is producing and likely to produce. For additional background, the make-up of the portfolio of projects in terms of technologies, organizational structure, company size, and other features is provided.

The individual project reports, within the particular technology area, follow the overview. The reports highlight major accomplishments and the outlook for continued progress. A detailed account of the project under review is given, with attention to technical and commercial goals and achievements, information about technology diffusion, and views about the role played by ATP funding. A performance rating is assigned to each project based on a four-star scoring system. The rating depends on the accomplishments of the project in creating and disseminating new scientific and technical knowledge and in making progress toward generating commercial benefits, as well as the outlook for continued progress.

Three appendices provide supporting information. Appendix A provides a listing of technical and commercial achievements of each completed project. Appendix B provides a discussion of the terminated projects throughout ATP's existence. Appendix C provides a list of the first 150 completed projects and the respective composite performance ratings. The listed is sorted in descending order of performance rating, then by company name.

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1. The current edition of the kit and other program materials may be obtained on ATP's website (www.atp.nist.gov), by e-mail (atp@nist.gov), by phone (1-800-ATP-Fund or 1-800-287-3863), or by mail (ATP, NIST, 100 Bureau Drive, Stop 4701, Gaithersburg, MD 20899-4701).
2. The Government Performance and Results Act (GPRA) is a legislative framework for requiring federal agencies to set strategic goals, measure performance, and report on the degree to which goals are met. An overview of the GPRA is provided in Appendix 1 of the General Accounting Office Executive Guide, Effectively Implementing the Government Performance and Results Act, GAO, Washington, D.C., GGD-96-118, 1996

Overview of Completed Projects

P A R T 1

Project Characteristics

This report provides an overview of the first 150 ATP-funded projects to reach completion. These projects reflect an investment of more than $621 million that was shared about equally by ATP and industry.

Of the initial 150 projects, 75 were led by small businesses that submitted single-company-applicant proposals to ATP. Eighty-seven percent involved collaborative relationships with other firms, universities, or both. Sixty-seven percent were funded in ATP's General Competitions.

In terms of classification by type, 25 percent of the projects were "Electronics, Computer Hardware, or Communications", while "Advanced Materials and Chemicals" accounted for 23 percent. "Manufacturing", "Information Technology", and "Biotechnology" each constituted about 17 percent of the remaining projects.

(The 150 completed status reports discussed in this chapter can be found on-line at http://www.atp.nist.gov/ under funded projects.)

Single Applicants and Joint Ventures

"Single-applicant projects," make up 81 percent of the first 150 ATP-funded projects; these projects were subject to an upper limit on ATP funding of $2 million and a time limit of 3 years. Nineteen percent of the 150 projects were joint ventures. Each of these projects had a minimum of two for-profit companies sharing research and costs for up to 5 years. Typically, the joint-venture membership included other for-profit companies, universities, and nonprofit laboratories. These projects, free of the funding constraint, tended to take on larger problems for longer periods of time.

Project Leaders

Figure 1-1 illustrates how project leadership of single-applicant and joint-venture projects was distributed among the various types of organizations. Small companies led most of the projects—75 of the 122 single-applicant projects and 8 of the 28 joint-venture projects. "Small" follows the Small Business Administration's definition and includes companies with fewer than 500 employees. Large companies—defined as Fortune 500 or

equivalent firms—led 31 of the single-applicant projects, or 25 percent, and eight of the joint ventures, or 29 percent. Medium-sized companies led only 14 single-applicant projects and one joint venture. Consortia led eight of the joint venture projects. Nonprofit institutions led two of the single-applicant projects[1], and three joint ventures.

Figure 1-1
Number of Single-Applicant and Joint-Venture Projects by
Type of Leadership
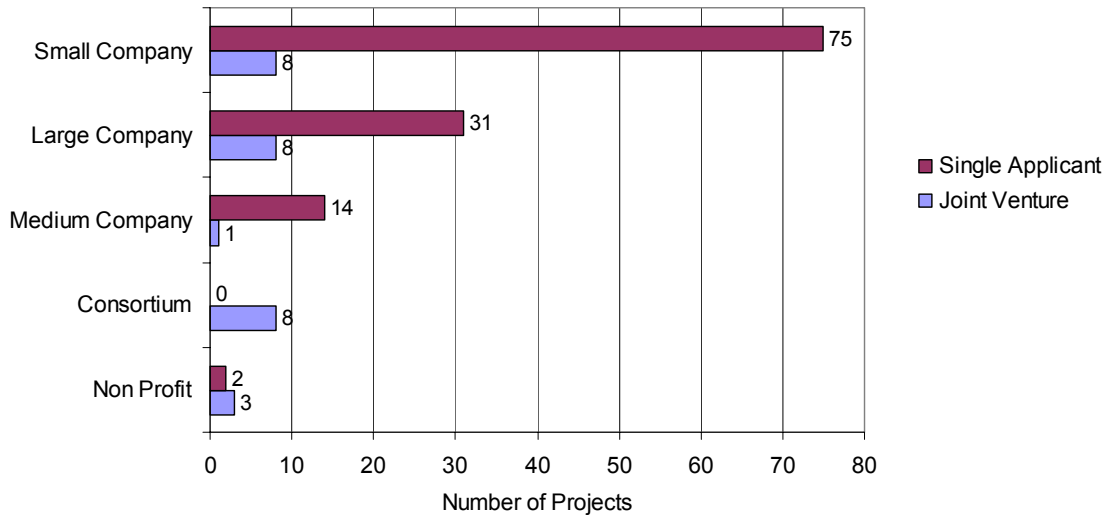
Source: Advanced Technology Program First 150 Status Reports

A Variety of Technologies

The 150 completed projects fall into the five technology areas used by ATP for classification purposes. Figure 1-2 shows the percentages of completed projects by technology area. The highest concentration, accounting for 25 percent of the total, is in "Electronics, Computer Hardware, or Communications." This category includes microelectromechanical technology, microelectronic fabrication technology, optics and photonics, and other electronics projects.

"Advanced Materials and Chemicals" account for 23 percent of the projects. "Information Technology," "Manufacturing," and "Biotechnology" account for, 19, 17 and 16 percent respectively of the 150 projects. The Manufacturing category includes areas such as energy conversion and energy generation and distribution, in addition to machine tools, materials handling, intelligent control, and other discrete manufacturing. The Advanced Materials and Chemicals category includes the subcategories of energy resources/petroleum, energy storage/fuel cell, battery, environmental technologies, separation technology, catalysis/biocatalysis, and other continuous manufacturing technologies, as well as metals and alloys, polymers, building/construction materials, and

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[1] From the 1991 competition, when nonprofits were eligible to lead ATP projects.

other materials. The category of Biotechnology includes areas such as bioinformatics, diagnostic and therapeutic, and animal and plant biotechnology.

Figure 1-2
Distribution of Projects by Technology Area
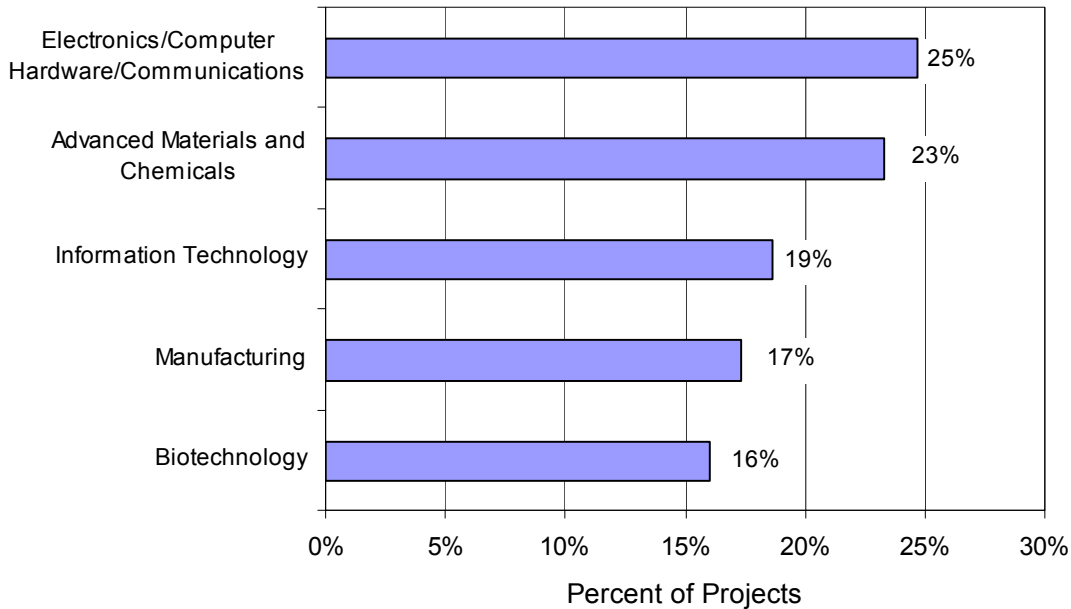
Source: Advanced Technology Program First 150 Status Reports

The technology make-up of these 150 projects differs from that of the larger ATP portfolio of projects in part because the composition of ATP applicants and awardees over time changes. Of the first 150 completed projects, 67 percent come from ATP's General Competitions that were open to all technologies, while 33 percent come from ATP's focused program competitions, which were held from 1994 through 1998. These competitions funded technologies in selected areas of focus, such as in Motor Vehicle Manufacturing Technology and Digital Video in Information Networks.

It should be noted that while the five major technology areas are used to classify the projects, most of them are not easy to classify. Most ATP projects involve a mix of technologies and interdisciplinary know-how.

Collaborative Activity

Although only 19 percent of the 150 projects were joint ventures, 87 percent of all projects had collaborative arrangements. As shown in Table 1-1, 49 percent of the projects involved close research and development (R&D) ties with universities. Sixty-one percent reported collaborating on R&D with companies or other nonuniversity organizations. Slightly less than half the projects formed collaborative relationships with other organizations for commercial pursuit of their ATP-funded technologies. Thirty-five

percent of projects had collaborative relationships with both universities and nonuniversities for either R&D or commercial purposes.

Table 1-1
Collaborative Activity

	Type of Collaboration	Percentage
A)	Collaborating on R&D with other companies or nonuniversity organizations	61%
B)	Close R&D ties with universities	49%
	Collaborating on R&D with other companies or nonuniversity organizations OR close R&D ties with universities (A or B)	75%
	Collaborating with both universities and non-university organizations (A and B)	35%
C)	Collaborating on commercialization with other organizations	46%
	Collaborating in one or more of the above ways	87%
Note: This assessment of collaborative relationships likely understates the numbers because it focused on the project's lead organization and probably missed some of the informal collaborative relationships of other participants.		

Source: Advanced Technology Program First 150 Status Reports

For more detail, Figure 1-3 illustrates the types of collaboration undertaken by projects with different forms of project leadership. It highlights the fact that under all forms of project leadership, projects were highly likely to involve collaboration with other companies. About 43 percent of the projects led by small and large companies involved university collaboration, while the share rose to 60 percent for projects led by medium-sized companies, and 75 percent for consortium-led projects.

Figure 1-3
**Number of Projects with R&D Collaborations by Type of Collaboration
and Type of Project Leadership**
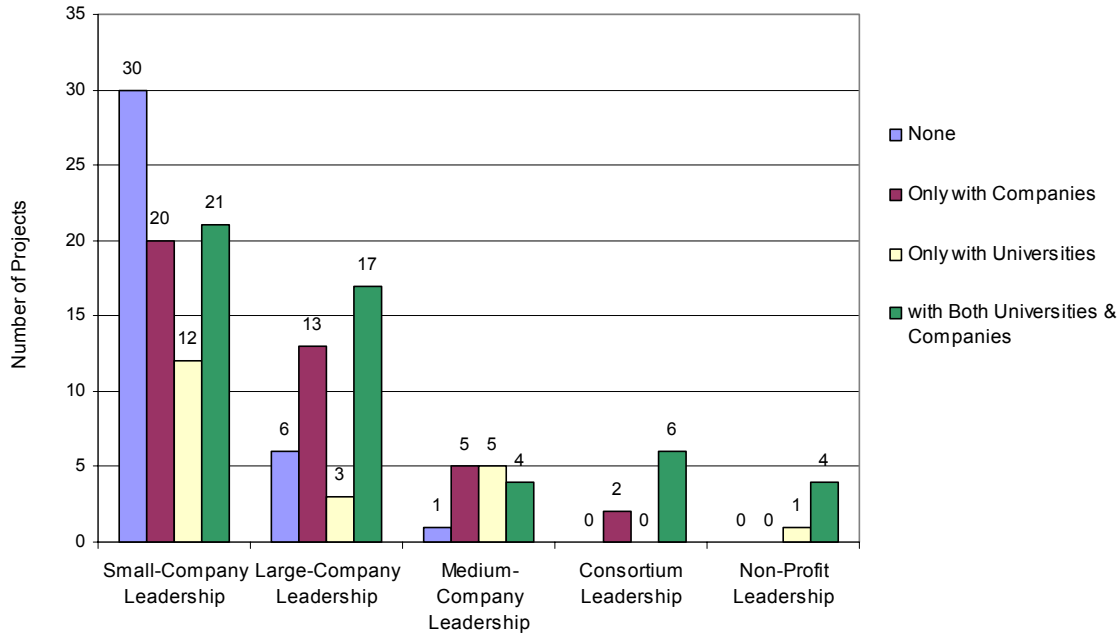
Source: Advanced Technology Program First 150 Status Reports

Costs of the Projects

As shown in Table 1-2, ATP and industry together invested in excess of $621 million on the 150 projects. They shared almost equally in project costs, with ATP providing a slightly larger share. ATP spent an average of $1.72 million per single-applicant project and an average of $3.97 million per joint-venture project. Across the 150 projects, the average total cost (ATP plus industry) per project was $4.14 million. Estimated benefits attributed to ATP from just a few of the 150 projects for which quantitative economic benefits have been provided exceed ATP's funding for all of the 150 projects. In addition, there is considerable evidence of large project benefits that have not yet been quantified.

Approximately 45 percent of single-applicant projects had total research costs under $3 million. These projects had an ATP share that ranged from a little more than $.5 million to $2 million. Slightly less than 50 percent had total research costs greater than $5 million, and one project had total research costs greater than $30 million. ATP's share of these costs were $2 million or more for 50 percent of the projects and were $5 million or higher for 36 percent. For one of the projects, ATP's share exceeded $10 million. Joint ventures, which made up only 19 percent of the total number of projects, accounted for 35 percent of total ATP funding.

Table 1-2
ATP Funding, Industry Cost Share, and Total Costs of 150 Completed Projects

	Single Applicant Projects	Joint Venture Projects	Total Projects
ATP Funding ($ Millions)	210.1	111.1	321.2
Industry Cost Share ($ Millions)	184.6	115.2	299.8
Total Project Costs ($ Millions)	394.7	226.3	621.0
ATP Share of Costs	53%	49%	52%
Industry Share of Costs	47%	51%	48%
Average Project Funding Provided by ATP ($ Millions)	1.72	3.97	2.14
Average Project Cost-Share Provided by Industry ($ Millions)	1.51	4.11	2.00
Average Project Funding Provided by Overall ($ Millions)	3.24	8.08	4.14

Source: Advanced Technology Program First 150 Status Reports

P A R T 2

Gains in Technical Knowledge

One of ATP's major goals is to build the nation's scientific and technical knowledge base. Each of the 150 completed ATP projects targeted a number of specific technical goals designed to achieve a new or better way of doing things. 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. It is a good starting place for assessing completed projects.

(The 150 completed status reports discussed in this chapter can be found on-line at http://www.atp.nist.gov/ under funded projects.)

New Technologies and Knowledge Gains

Knowledge gains by the projects are diverse and encompass the five major technology areas. The technologies developed in the 150 projects are listed in column C in Tables A-1–A-5 in Appendix A. The set of tables provides the reader with a convenient, quick reference to the entire range of technologies. The entries are arranged alphabetically, by project lead company using the five technology areas. As was mentioned earlier, most of these projects are interdisciplinary, involving a mixture of technologies and generating knowledge in multiple fields.

Even those projects that were not fully successful in achieving all of their research goals, or those that have not been followed by strong progress in commercialization, have achieved knowledge gains. Moreover, some of the projects carried out by companies that have since ceased operations or stopped work in the technology area yielded knowledge, as indicated primarily by the presence of publications and patents. In these cases the direct market routes of diffusion of knowledge gains through commercialization by the innovators are likely lost. However, the indirect routes—whereby others acquire and use the knowledge—remain.

Of What Significance Are the Technical Advances?

Measuring the significance of technical advances is challenging. One factor that challenges measurement is the length of elapsed time that typically separates an R&D investment and its resulting long-term outcomes. In the interim period, various short-run metrics may serve as indicators that project results appear to be on track toward achieving long-term goals. One metric that has been used to signal the significance of a project's technical achievements is formal recognition in the form of an award from a third-party organization.

Thirty awards for technical accomplishments were made to participants for achievements related to ATP-funded projects. Participants in 19 of the 150 projects received awards for their technical achievements. Participants in seven of the projects received multiple technical awards. Table 2-1 lists the awards made to these projects by third-party organizations in recognition of their technical accomplishments.

Table 2-1
Outside Recognition of Technical Achievements of the First 150 Completed Projects

Project Awardee	Year	Awarding Organization	Award
American Superconductor	1996	*Industry Week* Magazine	Technology of the Year award
American Superconductor	1996	*R&D* Magazine	One of the 100 most important innovations of the year
Automotive Composites Consortium (a Partnership of DaimlerChrysler [formerly Chrysler], Ford and General Motors)	1999	*Popular Science* Magazine	Best of What's New for the Chevrolet Silverado composite truck box, "a breakthrough in the use of structural composites"
Cincinnati Lamb, UNOVA (Lamb Technicon)	1999	*Industry Week* Magazine	Top 25 Technology and Innovation Award
Communication Intelligence #1	1997	Arthritis Foundation	"Ease-of-Use Seal of Commendation" for the development of natural handwriting technology, for use by disabled people who have trouble with keyboard entry
DuPont	1993	*Microwave & Rf* Magazine	One of the Top Products of 1993, for high-temperature superconductivity component technology
Ebert Composites	1999	Civil Engineering Research Foundation	Charles Pankow Award for Innovation in Civil Engineering
Engineering Animation	1994	*Computerworld* Magazine	Smithsonian Award, for the use of information technology in the field of medicine
Engineering Animation	1995	Association of Medical Illustrators	Association of Medical Illustrators Award of Excellence in Animation
Engineering Animation	1995	International ANNIE Awards	Finalist, received together with Walt Disney, for best animations in the film industry
Engineering Animation	1996	*Industry Week* Magazine	One of the 25 Technologies of the Year, for interactive 3D visualization and dynamics software used for product development
GM Thermoplastic Engineering Design (Engineering Design with Thermoplastics)	2001	Internal GM R&D Award	Campbell Award for "Process Modeling and Performance Predictions of Injection-Molded Polymers"
GM Thermoplastic Engineering Design (Engineering Design with Thermoplastics)	2001	Society of Plastics Engineers	Best Paper Award from the Product Design and Development Division

Project Awardee	Year	Awarding Organization	Award
HelpMate Robotics	1996	*Discover* Magazine	One of 36 finalists for Technology of the Year, for the HelpMate robot used in hospitals
HelpMate Robotics	1997	Science Technology Foundation of Japan	Japan Prize, to CEO Joseph Engelberger, for "systems engineering for an artifactual environment"
Illinois Superconductor	1996	*Microwave & Rf* Magazine	One of the Top Products of 1996, for cellular phone site filters and superconducting ceramics
Illinois Superconductor	1997	American Ceramic Society	Corporate Technical Achievement Award
Integra Life Sciences**	1999	New Jersey Research and Development Council	Thomas Alvin Edison Award
Kopin Corporation	1998	*Electronic Products* Magazine	"Product of the Year" Award for expanding functionality of portable devices including PDAs, cell phones, and pagers
Kopin Corporation	1998	*IndustryWeek* Magazine	"25 Technologies of the Year" Award
Kopin Corporation	1999	*Photonics Spectra* Magazine	"25 Most Technically Innovative Products" Award for the CyberDisplay 320C
Kopin Corporation	2003	Consumer Electronics Show 2003	"Best Innovation" Award for the 44-inch LCoS HDTV
Molecular Simulations	1996	Computerworld Magazine	Finalist for Smithsonian Award, the 1996 Innovator Medal
NCMS	1994	Institute for Interconnecting & Packaging Electronics Circuits	Best Paper of Conference Awards
Perceptron (formerly Autospect, Inc.)	1998	International Body Engineering Conference	Best Paper Award
Strongwell Corporation	1998	Composite Fabricators Association Conference	Best of Show Award
The Dow Chemical Company	2004	Department of Commerce, NIST/Brookhaven	Gold Medal for Scientific/ Engineering Achievement for Dr. Daniel Fischer's work on "a unique national measurement facility for soft X-ray absorption spectroscopy enabling breakthrough materials advances"
Xerox Palo Alto Research Center	2003	*JavaWorld*	Editors' Choice Award for the Most Innovative Java Product or Technology
X-Ray Optical Systems (XOS)	1995	*R&D* Magazine	R&D top 100
X-Ray Optical Systems (XOS)	1996	*Photonics Spectra* Magazine	Photonics Circle of Excellence Award

Source: Advanced Technology Program First 150 Status Reports

**The award went to Dr. Kohn of Rutgers University for his collaborative work with Integra on the project.

Examples of Projects with Knowledge Gains

Xerox Palo Alto Research Center: Xerox Palo Alto Research Center (PARC) expanded its research on modularity with a cost-shared award for $1.7 million from ATP's Component-Based Software Focus Program. The project began in 1995, and the researchers developed two prototype applications that extracted system-wide concerns into separate modules with their own code. They called this approach aspect-oriented programming (AOP).

As ATP funding ended, PARC began working with the Defense Advanced Research Projects Agency to create a general-purpose language and tool, which PARC patented and called AspectJ. This product:

- Is freely available through IBM's eclipse.org web site
- Has six trade books devoted to it
- Won the JavaWorld Editors' Choice Award for the Most Innovative Product or Technology in 2003
- Is used aggressively by IBM in developing new software products

AOP is well recognized in the computer industry and has eight patents associated with it. More than a dozen universities in North America and in the United Kingdom include it in their curricula. Although the average computer user does not know or care about aspects, programmers' use of AOP in designing web sites will bring speed, reliability, greater customization, and savings. End users receive better services, delivered more quickly, at a lower cost.

Orchid BioSciences (formerly Molecular Tool, Inc. Alpha Center): A small company, Molecular Tool, applied for and was awarded $1.9 million under the ATP Tools for DNA Diagnostics focused program in 1995, in order to compress most of the functions of SNP analysis that were being done in the 20-foot by 15-foot biotechnology laboratory onto a 1-square-inch glass chip..

Molecular Tool successfully developed a patented prototype SNP analysis tool in 1998 and gained the attention of the biotechnology industry. Orchid BioComputer (later renamed Orchid BioSciences) purchased Molecular Tool in 1998 to acquire the ATP-funded equipment and the company's project-related knowledge.

In 2000, Orchid BioSciences was performing DNA analyses using a single nucleotide polymorphism (SNP) analysis tool, which performed more than 800,000 DNA analyses per day. Orchid's SNP scoring tool, called SNPstream, analyzes up to 100,000 data points for increased accuracy. Furthermore, a typical result showed one in several billions statistical probability, increased from one in a million. SNP technology has had high-profile applications:

- Used to attempt to identify the remains of some New York City World Trade Center victims of 2001, which could not be identified by conventional DNA analysis due to sample degradation.

- Used in assisting major metropolitan police departments in forensics, including Los Angeles, Houston, and England's Scotland Yard. Also developed advanced forensic applications to identify individuals from unsolved crimes using degraded DNA samples for the Federal Bureau of Investigation. Orchid's express DNA service provides forensic DNA analyses in five business days compared with the standard four to five weeks.

- Used for the United Kingdom's scrapie genotyping program to help sheep farmers use selective breeding to eliminate the disease scrapie from their flocks. The company has genotyped over 1 million sheep to date.

The societal benefits of SNP analyses are growing. Typical DNA analysis cost has been reduced by approximately 70 percent, and the time it takes to perform DNA analysis has been reduced by approximately 75 percent, such that DNA analysis can now provide results in about a week (reduced from 4 weeks). Police departments are able to solve cold cases, because SNPstream is able to analyze DNA from degraded samples. It is hoped that pharmacogenetic applications (studying genetic variations related to the onset of disease, and pharmaceuticals) will improve medical treatment.

SciComp: ATP provided in cost-shared funds to $1.9 million to SciComp to develop a software synthesis technology that would simplify the process of mathematical modeling.

SciComp, Inc successfully incorporated simplified mathematical modeling (representing a mathematical device or process) into software for the derivative securities industry. Called SciFinance, this solution includes tools that can automate the pricing of complex derivative securities, organize libraries of pricing codes, and provide risk-management analysis.

As of 2004, SciFinance includes six financial products, four of which incorporate the ATP-funded synthesis technology and two that enhance the other products.

SciComp's software synthesis technology improved the productivity of mathematical modelers by tenfold. SciComp has been awarded two patents based on ATP-funded technology development, and the company has shared knowledge through nine published papers and made several presentations at conferences.

As of 2004, the volume of derivative securities trading has continued to grow, resulting in increased demand for software tools to assist in the pricing of complex derivative structures. SciComp is one of only a few companies that provide these tools.

P A R T 3

Dissemination of Knowledge

If knowledge from the projects is disseminated—either through products and processes commercialized by the innovators or through publications, patents, and other modes of knowledge transfer—it may benefit other producers in the economy and, subsequently, consumers. The resulting national benefits may go far beyond the returns to the innovating firms and the benefits to their customers.

(The 150 completed status reports discussed in this chapter can be found on-line at http://www.atp.nist.gov/ under funded projects.)

Multiple Ways of Disseminating Knowledge

New knowledge developed in a project can be diffused in a variety of ways. This section discusses two principal means: through patents filed and granted by the U.S. Patent and Trademark Office (USPTO) and cited by others, and through preparation of technical papers that are published or are presented at conferences. Collaborative activity among research and commercial partners, treated in Part 1, is another way by which knowledge is disseminated. Another way is through the observation and reverse engineering of the new goods or services produced directly by the innovators and their partners, discussed in Part 4. Among the other important ways—not explicitly covered here—in which knowledge developed in a project can be diffused are informal interactions among researchers, suppliers, customers, and others; movement of project staff to other organizations; distribution of nonproprietary project descriptions by government funding agencies; and project-related workshops and meetings.

Pathways of knowledge dissemination allow others to obtain the benefits of R&D without having to pay its full cost. When the technology is particularly enabling—in the sense of providing radically new ways of doing things, improving the technical bases for entire industry sectors, or being useful in many diverse areas of application—the spillover benefits to others are likely to be particularly large. The generation of spillover benefits, or positive externalities, from technological advancement is an important argument for public support of enabling technologies.

Balancing Intellectual Property Protection and Knowledge Dissemination

ATP encourages broad dissemination of knowledge produced in ATP-funded projects because it increases the number of potential users of the knowledge and, therefore, may increase national benefits. At the same time, ATP does not force innovating companies to compromise their ability and willingness to pursue early commercial applications of the technology by giving away all of their intellectual property. After all, these companies,

which contribute a substantial share of the costs, have agreed to tackle difficult research barriers and to take the technology to the marketplace as rapidly as possible.

Thus, it is not surprising that the amount of knowledge dissemination varies among the projects. Most of the projects pursue some forms of deliberate knowledge dissemination, such as publishing scientific papers, giving presentations, and forming collaborative relationships. Most projects also engage in considerable unintended knowledge dissemination; for example, as a company's scientists move and work among other companies and universities; as myriad formal and informal discussions occur; as others reverse-engineer their products; and through mergers and acquisitions of the innovating companies.

Public Disclosure of Patent Filing Information

When applying for a patent to protect intellectual property, an inventor must explicitly describe the invention. Because patent law requires that the invention is both novel and useful, the inventor must demonstrate that the invention is essentially different from any other invention and must describe how it can be used. When the USPTO grants a patent, the full application text describing how the invention may be used and how it is related to other technologies is put into the public record and becomes a medium through which knowledge is transferred to others. Hence, patents serve to disseminate knowledge.

At the same time, patent data are not perfect signals of knowledge creation and dissemination. The decision to seek patent protection for intellectual property is influenced by many factors, including the ease with which others can copy the property's intellectual content and the difficulty of defending the patent position from infringement. Some companies may decide that patent protection is not worth its expense or that a strategy of trade secrets and speed-to-market is more effective. Conversely, patents may be filed as the basic ideas are forming, and trade secrets used in later stages. Furthermore, the importance of patents as a strategy varies among technology areas; for example, patents figure more strongly in electronics and manufacturing than in computer software. The absence of a patent does not mean that intellectual property was not created. But the presence of a patent is a signal that it was created. Despite the limitations, patent statistics serve as useful indicators of knowledge creation and dissemination, and they are widely used by researchers.

Of the 150 completed projects, 89 had filed 500 patents at the time the study data were collected.[2] Eighty-one of the projects had among them a total of 347 patents granted, or 70 percent of the total filed. Thirty-two of the projects had filed a total of 153 patents for which a final decision on granting was still pending.

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[2] Patents filed and not yet granted are included here, in addition to those filed and granted, despite the fact that there is no public disclosure until patents are actually granted. The reason for including patents filed and not yet granted is to help offset the problem that there are substantial differences across industries in the lag time between patent filing and granting.

Figure 3-1 displays the distribution of the 150 projects by the number of patents filed, whether granted or not yet granted. More than half the projects have filed one or more patents. Participants in 12 percent of projects had filed a single patent, 26 percent had filed 2 to 4 patents each, and 22 percent had filed 5 or more patents. Forty percent of the projects had not filed a patent.

Figure 3-1
Distribution of Projects by Number of Patents Filed
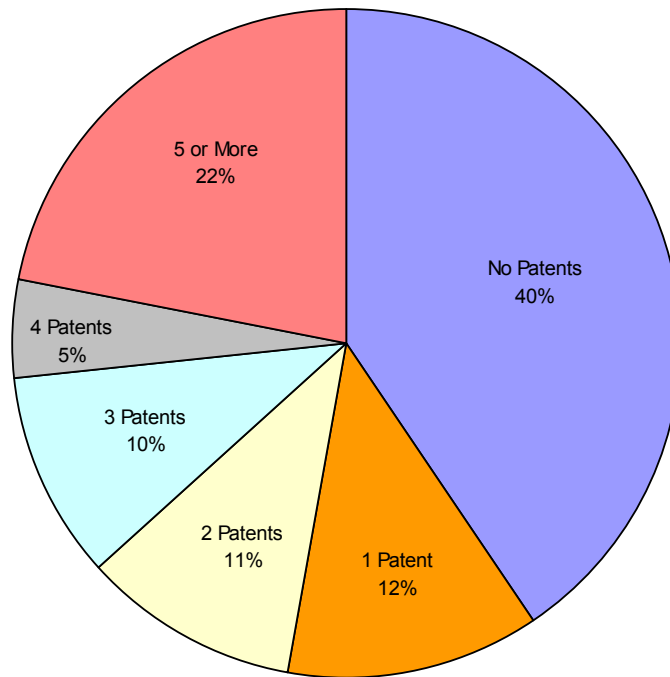
Source: Advanced Technology Program First 150 Status Reports

Knowledge Disseminated by Patents as Revealed by Patent Trees

Each published patent contains a list of previous patents and scholarly papers that establish the prior art as it relates to the invention. The citations provide a way to track the spread of technical knowledge through patents granted to ATP-funded projects. By following the trail of the patent referenced, it is possible to construct what looks much like a horizontal genealogy tree.

Once the pool of ATP-related patents was identified, computerized tools made available by the USPTO were used to track subsequent patents that refer to each of the ATP-related patents as prior art and the links recorded.[3] The process is then repeated in turn for each of these patents, until the chain of references is complete. Next, the information is

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[3] The references to prior patents contained in a published patent are based on information supplied by the applicant and on research by USPTO researchers. There is no way to distinguish between the two sources and no indication that one tends to dominate the other. (USPTO telephone interview with ATP staff, February 11, 2000.)

converted into a graphic format that illustrates the diffusion of knowledge along the path from ATP project patents in the tree.

With the passage of additional time, new branches may emerge as outgrowths of earlier patents. To the extent that later patents are dependent on the earlier ones, the patents in the tree represent developments in knowledge that would not have occurred, or at least not in the same timeframe, had ATP not stimulated the creation and dissemination of that platform knowledge.

Patent Tree Illustrating Knowledge Dissemination

The patent tree in Figure 3-2 shows citations of a patent that came out of an ATP-funded project led by **Texas Instruments, Inc.** during which the company developed a special insulating material, known as aerogel, to overcome problems with interconnect delays as a result of the continuing trend toward miniaturization. The company overcame impediments to aerogel processing early in the project, but in 1997, an industry competitor announced that it would begin using copper interconnect wiring in future integrated circuit designs. After the ATP-funded project Texas Instruments shifted focus away from aerogels for aluminum and began to develop copper interconnects.

The patent tree illustrates how an ATP-funded project whose direct path appears to have slowed or has come to a standstill nevertheless has the potential to remain influential along an indirect path of knowledge utilized and cited in subsequent patents. As the patent tree illustrates, a number of other companies are referencing the Texas Instrument patent, and the potential for beneficial impact from the research continues.

Figure 3-2
Patent Tree for Texas Instruments, Inc. - Patent 5,894,173
Project Impact After Innovator Reduced Activity
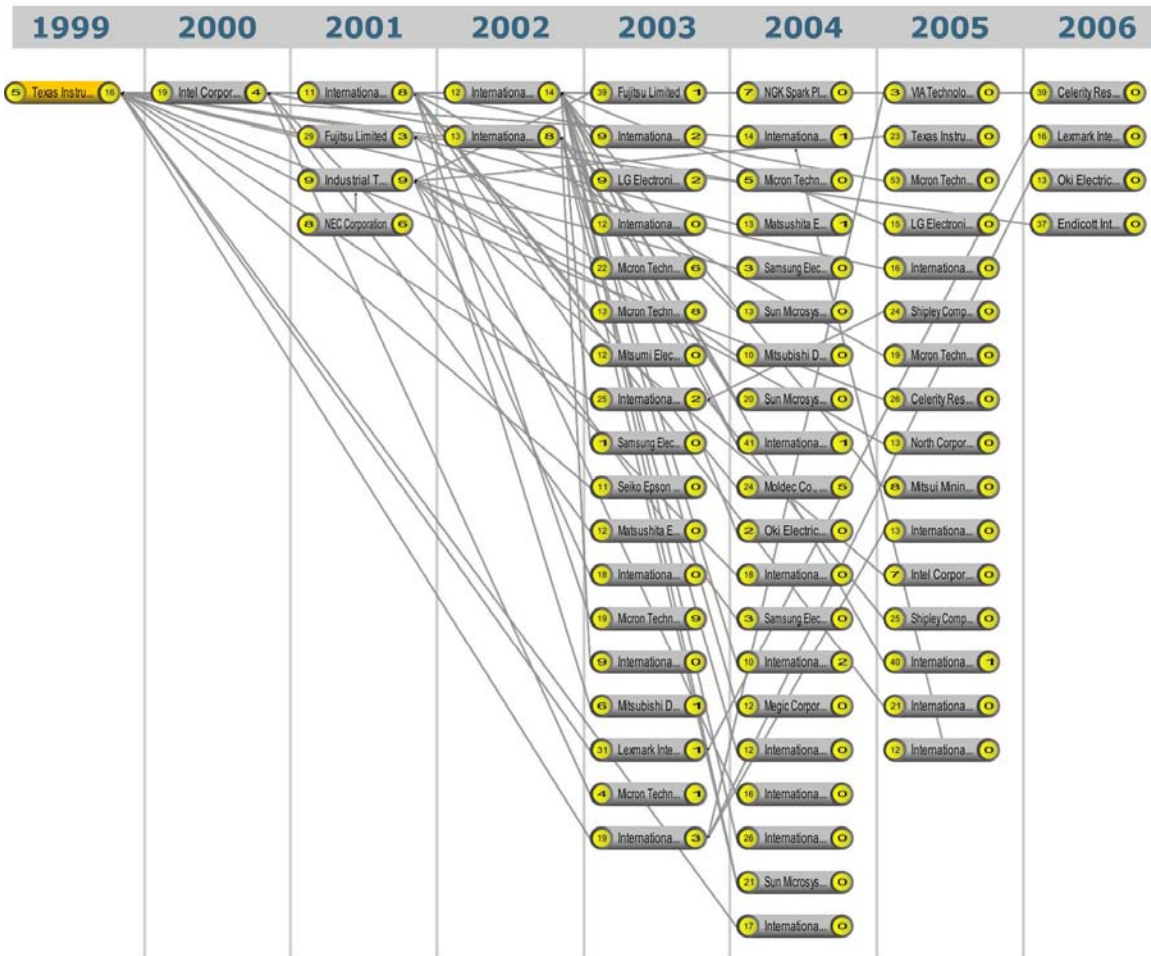
Figure 3-3
Patent Tree for Large Scale Biology Corporation - Patent 5,993,627
Project Impact Where Innovator Went Bankrupt
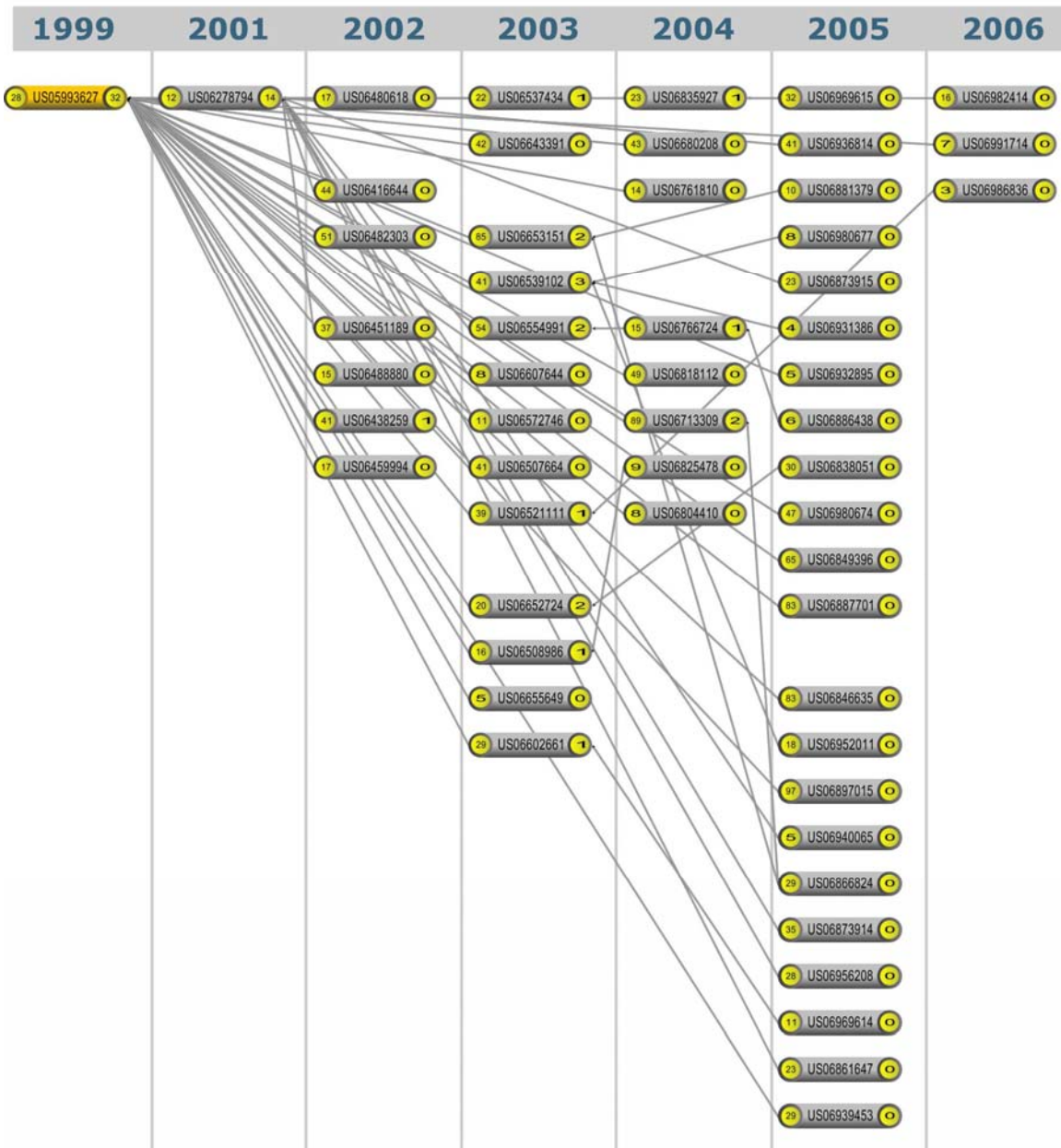
Figure 3-3 shows citations of a patent resulting from a project led by **Large Scale Biology Corporation**. Though the company went bankrupt, the patent tree illustrates how knowledge can outlive its creator and continue to be disseminated. An observer who equates business success of the innovator, one-to-one, with ATP project success may be mistaken, because the indirect path may nevertheless produce important benefits.

Patent Tree Illustrating Extensive Knowledge Flows

Figure 3-4 illustrates just how complex knowledge dissemination through patent citations can become. The path shown is for a patent resulting from an ATP-funded project led by **JDS Uniphase (formerly SDL, Inc.)** and **Xerox Corporation**. With the ATP award, the research team successfully developed high-performance, multibeam red laser diodes; two alternative methods for monolithic integrations of red, infrared, and blue emitters; and several valuable intermediary technologies. From these successes, the ATP-funded project built a strong U.S. technology base for multiple laser applications. Eighty-four inventions from this project have been commercialized into numerous products. This single Xerox patent resulted in approximately 110 citations.

For projects that have received a patent or patents, access to patent trees is available through the individual status reports on the NIST ATP website (http://statusreports-atp.nist.gov/basic_form.asp). Although representing only one aspect of knowledge dissemination, the patent trees extend awareness of the influence of the new knowledge.

Figure 3-4
Patent Tree for Xerox Corporation - Patent 5,963,447
Example of Extensive Knowledge Flows
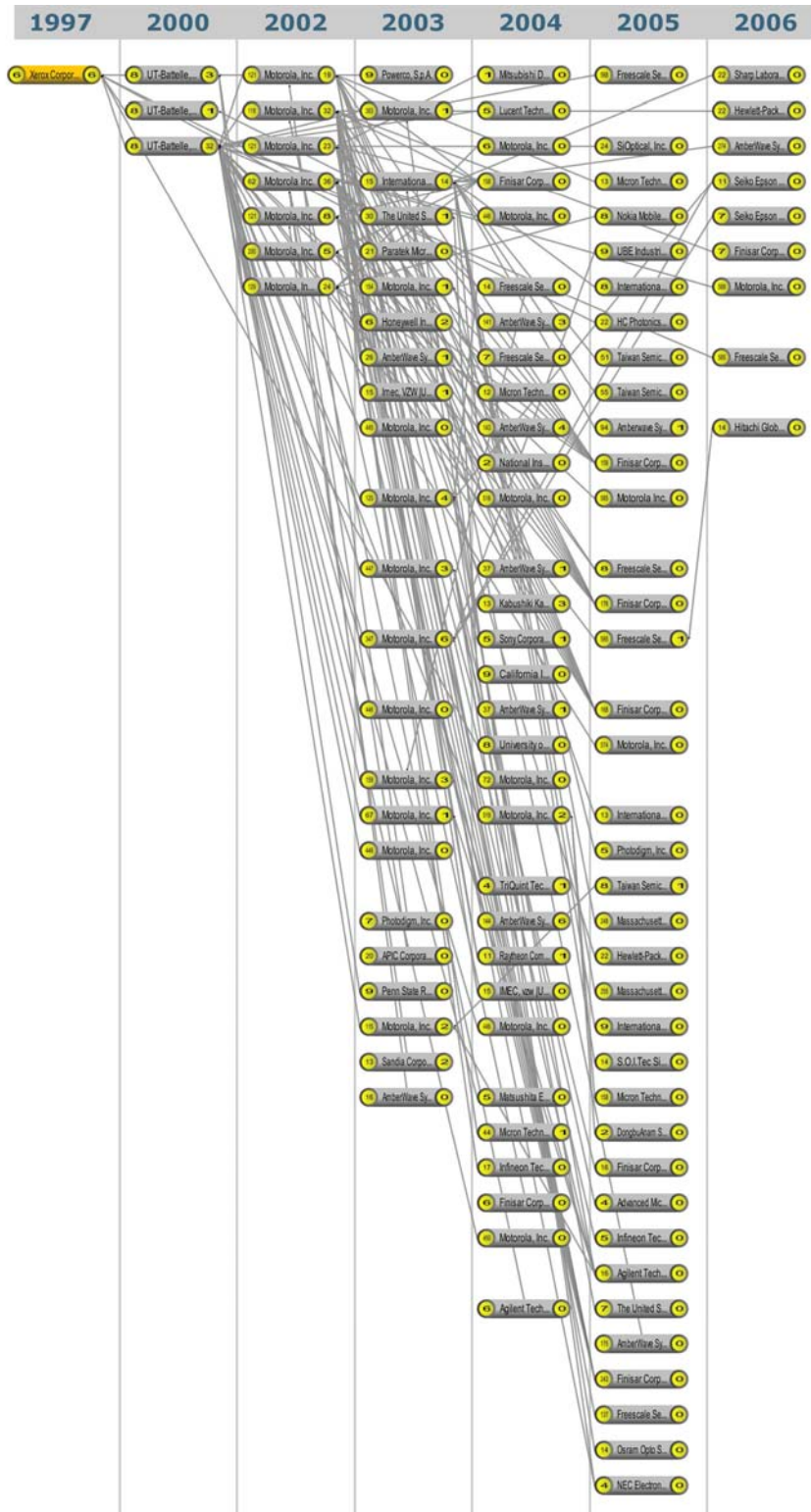
Knowledge Dissemination through Publications and Presentations

Participants in almost 66 percent of the 150 projects had published or had presented papers in technical and professional journals or in public forums. Participants in more than half of all projects had published, and the number of publications totaled at least 831 papers. Participants in nearly 47 percent of the projects had given project-related presentations, and the number of presentations totaled at least 739. Overall, publications and presentations for these 150 projects equaled or exceeded 1570.

Figure 3-5 gives the distribution of projects by their numbers of publications and presentations. Twenty-nine percent of the projects each had between one and five papers published or presented. Nine percent had between 6 and 10 papers published or presented, and another 14 percent had between 11 and 20. At the high end, 14 percent of projects each had more than 20 papers published or presented. Thirty-three percent had no known presentations or publications.

Figure 3-5
Distribution of Projects by Number of Publications and Presentations
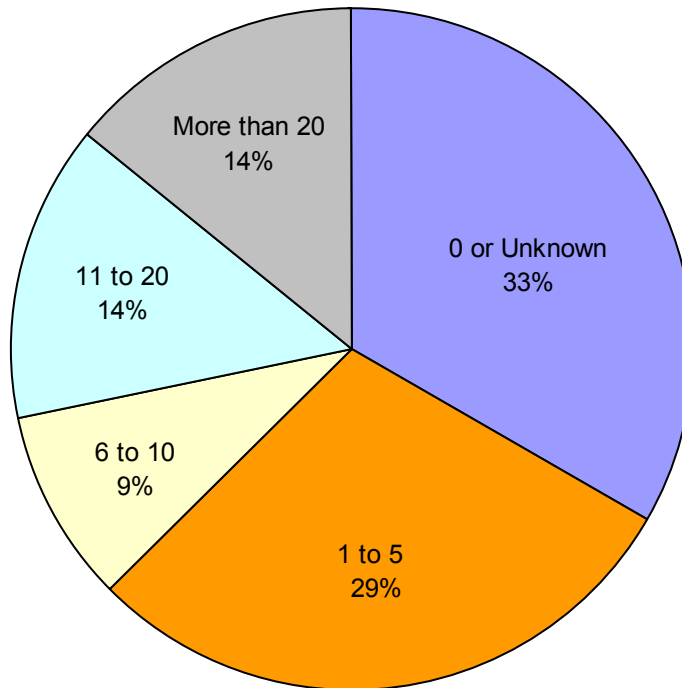
Source: Advanced Technology Program First 150 Status Reports

Knowledge Dissemination through Other Means

Aside from publishing, presenting, and patenting, ATP-funded projects have a high rate of collaborative activities. Eighty-seven percent of the projects showed some type of collaboration (see Table 1-1). With so many partners, collaborators, and subcontractors involved, it would be difficult to secure the information. The involvement of so many participants in the projects provides rich avenues of further interaction, and those interactions in turn may increase knowledge flows through personal and professional contacts.

When the government enters into an agreement with an organization, certain information about the agreement is generally made public. Such is the case with ATP and company cost-sharing partnerships. Nonproprietary information has been disclosed to the public for each of the 768 projects funded by ATP in 44 competitions held from 1990 through September 2004 (project information is available on the ATP website[4]). Further, new nonproprietary project descriptions are added to the site as new awards are made. Evaluation reports, such as this one, are also available at ATP's website and provide information to the public.

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[4] http://jazz.nist.gov/atpcf/prjbriefs/listmaker.cfm or http://atp.nist.gov (go to Funded Projects Database).

P A R T 4

Commercialization of the New Technology

New technical knowledge must be used if economic benefits are going to accrue to the nation. This generally means that a new product or process is introduced into the market by the innovating firm, its collaborators, or other companies that acquire the knowledge. In competitive markets, the producer is typically unable to capture all the benefits of a new product or process, and the consumer reaps part of the benefits. The higher up the supply chain the innovation occurs, the more value-added steps there are before final consumption, and the more intermediate firms in the supply chain may benefit, in addition to the final consumer.[5]

(The 150 completed status reports discussed in this chapter can be found on-line at http://www.atp.nist.gov/ under funded projects.)

Commercialization of Products and Processes—A Critical Step Toward National Benefits

When a product or service incorporating new technology reaches the marketplace, a buyer can learn a great deal about the technology. The mere functioning of a new product reveals some information. Intentional investigation, including reverse engineering, reveals even more. More than 60 percent of the 150 projects reviewed for this study had some commercial products or processes based on ATP-funded technology already on the market. Therefore, product use and examination are providing others with information about the new technologies.

Ninety-one of the projects had already spawned or expected to bring to market 222 new products or processes when the data for this report were collected. Companies in 18 additional projects expected to achieve their first commercialized results shortly[6], and

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[5] For a detailed treatment of the relationship between spillover benefits (knowledge, market, and network spillovers) and commercialization, see Adam B. Jaffe, *Economic Analyses of Research Spillovers: Implications for the Advanced Technology Program*, GCR 96-708, (Gaithersburg, MD: National Institute of Standards and Technology, December 1996). He notes: "Market spillovers will not be realized unless the innovation is commercialized successfully. Market spillovers accrue to the customers that use the innovative product; they will not come to pass if a technically successful effort does not lead to successful commercialization" (p. 12). In commenting on spillovers that occur because new knowledge is disseminated to others outside the inventing firm, he observes: "Note that even in the case of knowledge spillovers, the social return is created by the commercial use of a new process or product, and the profits and consumer benefits thereby created" (p. 15).

[6] "Shortly" refers to the time when the question is asked. Since Status Reports are written about 5 years after ATP funding ends, the perspective is the same for all status reports. So, when a company answers that

companies in 17 projects that had already commercialized their technology expected to add new products and processes soon. Thus, 73 percent of the projects had spawned one or more products or processes in the market or were expected to do so shortly, for a total of 245 products or processes either on the market or expected shortly after the time the data were collected. Table 4-1 summarizes the commercialization results.

Table 4-1
Progress of Participating Companies in Commercializing the
New Technologies

Degree of Progress	Number of Projects	Number of Products/Processes
Project has resulted in at least one Product/Process on the market AND additional Products/Processes are expected soon	17	63
Project has resulted in at least one Product/Process on the market, but no additional Products/Processes are expected soon	74	159
Project is expected to result in a Product/Process on the market soon, but no Product/Process is currently on the market.	18	23
Total Projects that have resulted in Products/Processes on the market OR are expecting to have Products/Processes on the Market soon.	109	245

Source: Advanced Technology Program First 150 Status Reports

A number of additional years have passed since the data for the first 150 projects were collected. Since that time, further developments have doubtless occurred with these projects, which have changed their commercialization results. This overview reports commercial progress of the first 150 projects, all at approximately comparable times following their completion.

A Quick Glance at the New Products

A variety of new products and processes resulted from the projects. For a convenient, quick reference, brief descriptions of the new products or processes for each project are listed in column D in Tables A-1–A-5 in Appendix A. For each new product or process, the new technology on which it is based is also listed in the tables, in column C.

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they expect a product or process on the market soon or shortly, they are referring to new product commercialization in the next 3 to 12 months.

Commercialization: A Critical Step, but Not the Final Word

Commercializing a technology is necessary to achieve economic benefit, but it does not ensure that the project is a full success from the perspective of either the company or ATP. Widespread diffusion of the technology may or may not ultimately follow the initial commercialization. Nevertheless, it is significant that these products and processes are actually on the market.

Rapidly Growing Companies

Rapid growth often signals that a small innovating company is on the path to taking its technology into the market, and one dimension of company growth typically is its employment gains.[7]

Figure 4-1 shows employment changes for the 75 small-company, single-applicant ATP award recipients.[8] Twenty-seven percent of these companies experienced job growth in excess of 500 percent from the beginning of the project until several years after the project had completed. Thirty-two percent —the largest share— experienced job growth in excess of 100 percent, ranging up to 500 percent. Mergers and acquisitions accounted for 20 percent, or nine of the 45 projects that experienced substantial job growth (substantial job growth being in excess of 100 percent).

Not all the small companies grew. A little more than one-quarter of them experienced no change or a decrease in staff. Several of the companies that were small when they applied to ATP grew so rapidly they moved out of the small-size category. As a group, of the 75 small single-applicant companies, 45 companies at least doubled in size; 14 of them grew more than 1,000 percent. ATP helped these companies develop advanced capabilities, which they subsequently leveraged into major business endeavors.

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[7] Employment within the small companies is considered as an indicator of commercial progress. Assessing macroeconomic employment gains from the technological progress stimulated by the 150 projects is beyond the scope of this report.

[8] Employment changes in joint ventures, larger companies, and nonprofit organizations are less closely tied to the success of individual research projects, and, therefore, are not included in the employment data in Figure 4-1.

Figure 4-1
Employment Change at Small Companies that Received a
Single-Applicant Award
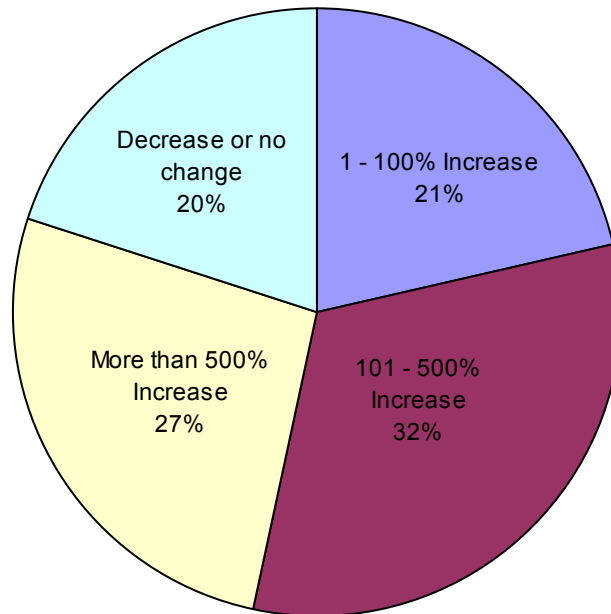
Source: Advanced Technology Program First 150 Status Reports

The following examples illustrate the potential impact of ATP funding on the employment growth of funded companies.

Incyte Corporation grew from 4 to 215 employees due to the development of flexible techniques for manufacturing chem-jet-based microarrays. The technique synthesizes large arrays of specific DNA fragments suitable for medical diagnosis, microbial detection and DNA sequencing, and for creating supplies of detachable oligonucleotides for subsequent use. (Project number 94-05-0019)

Nanophase Technology increased employment from 2 employees at the start of the ATP project to 61 employees at the time the status report was written. The employment is a result of Nanophase's development of a technology that enabled a 25,000-fold increase in the development of nanoscale materials and a 20,000-fold reduction in cost. (Project number 91-01-0041)

Capital Attraction

Attraction of additional capital is another signal that a company is positioned to make further progress. Of the 150 projects, 104 had attracted additional capital to further pursue development of their technologies. Additional funding came variously from collaborative partners, venture capitalists, public offerings of stock, other governmental departments including state government programs, and other sources.

Members of the **Genosensor Consortium** attracted additional internal funding after successfully developing a technology for automated DNA sequence analysis during the ATP-funded project. (Project number 92-01-0044)

eMagin Corporation received a $3 million grant from the U.S. Air Force after successfully developing microdisplays that have been integrated into hundreds of medical, commercial, and military applications. (Project number 93-01-0154)

ABB Lummus attracted additional internal capital after the ATP project as a result of the company's successful development of a new, environmentally superior process to manufacture alkylate using solid-acid catalysts. (Project number 95-05-0034)

The Dow Chemical Company also attracted additional capital due to the methodologies developed during the ATP project to create a direct, economical, single-product oxidation process incorporating a silver-based catalyst for conversion of propylene to propylene oxide. (Project number 95-05-0002)

P A R T 5

Overall Project Performance

The individual performance of the 150 completed projects has varied, as, measured by the creation and dissemination of knowledge and the accelerated use of that knowledge for commercial purposes. Some of the award-recipient companies grew by leaps and bounds as they translated their knowledge gains from ATP-funded research into profitable and beneficial products, services, and production processes. Some continued to strive toward hard-to-achieve goals, while others showed little outward signs of further progress. A few that achieved impressive research accomplishments later failed in the commercialization phase. However, the achievements of the more successful projects, with their impressive new performance capabilities resulting in lower costs and higher quality products and processes, appear to have much more than compensated for the less successful projects. There is considerable evidence that the benefits attributable to ATP from the 150 completed projects substantially exceed their costs.

(The 150 completed status reports discussed in this chapter can be found on-line at http://www.atp.nist.gov/ under funded projects.)

Composite Performance Scores

During the intermediate period covered by this analysis—after project completion but before long-term benefits have had time to be realized—ATP uses a Composite Performance Rating System (CPRS) to help gain a sense of how projects in the portfolio have performed overall thus far against ATP's mission-driven multiple goals.[9] In this intermediate period of project life cycles, the focus is on progress toward the goals of 1) knowledge creation, 2) knowledge dissemination, and 3) commercialization. The CPRS uses a weighted composite of output data systematically collected for each of the 150 projects—some of which have been presented in aggregate form in the preceding sections of this overview—to assess overall performance of the portfolio of completed projects in this intermediate period.

The output data serve as indicator metrics of progress toward achieving goals. Examples of available indicator metrics signaling progress toward the creation and dissemination of knowledge are a) awards for technical excellence bestowed by third-party organizations,

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[9] For an in-depth treatment of the CPRS, which was developed in prototype for ATP's use, see Rosalie Ruegg, *Bridging from Project Case Study to Portfolio Analysis in a Public R&D Program*, NIST GCR 03-851 (Gaithersburg, MD: National Institute of Standards and Technology, 2003).

b) patent filings, c) publications and presentations, d) knowledge dissemination from potential reverse engineering of new and improved products/processes on the market or expected soon, and e) collaborative activity. Available indicator metrics signaling progress toward commercialization of the new technology include a) attraction of additional capital, b) employment gains, c) project-related company awards for business success, d) moving products and processes into the market, and e) analysts' outlooks for future progress by the award-recipient companies.

Weights are assigned to the indicator data, which are combined to produce a composite numerical score that is then converted to a zero- to four-star rating for each project. A score of one star or less signals poor overall performance; two stars, moderate performance; three stars, strong performance; and four stars, outstanding performance. The distribution of CPRS scores computed for each project in a portfolio of projects is then examined, and the results taken as indicative of overall portfolio performance.

The resulting CPRS ratings provide an easy-to-grasp highlighting of portfolio performance in the intermediate period. They call out those projects that have exhibited outstanding or strong outward signs of progress towards long-run program goals during the years covered and those that have exhibited moderate or few signs of progress. However, the ratings are imperfect and should be viewed as only roughly indicative of overall performance.

The performance metrics are consistent with the view of varying degrees of success—with knowledge creation and dissemination constituting partial success, and a continuation into commercialization constituting a fuller degree of success in terms of project progress. Some companies carried out their proposed research with a degree of success during the time of ATP funding, but then did not continue pursuit of their project's larger goals after ATP funding ended. At this stage of evaluation, ATP considers such projects only partial successes, because the direct path for achieving project goals is truncated. Such projects are not among the higher scorers in this report. It is possible, however, that developments along the indirect path (diffusion of knowledge from the project through publications, presentations, patents, and licensing) may nevertheless occur—particularly if a project produced effective knowledge transmitters, such as patents and publications. It is also possible that a company may work in secrecy for a long period of time with no visible outputs and then suddenly explode on the scene with a single output that will yield large societal benefits.

Limiting factors include the extent to which not all relevant effects are captured; moreover, the use of indicator metrics is constrained by data availability, the development of the weighting system is empirically driven rather than theoretically based, and the ratings do not directly measure national benefits. The degree of correlation between a project's performance score and its long-run societal benefits is impossible to know at this time. Projects with the same scores are not necessarily equal in their potential benefits. They are, however, somewhat comparable in terms of the robustness of their progress to date.

Scoring the First 150 Completed Projects

The distribution of CPRS scores for ATP's first 150 completed projects is shown in Figure 5-1. Combining the two and three-star categories shows 56 percent of projects performed at a moderate level. Thirteen percent of the projects performed at a high (four-star) level and approximately 30 percent of the projects scored one star or less, perhaps not surprising for companies taking on difficult goals.

Figure 5-1
Distribution of Projects by Star Rating
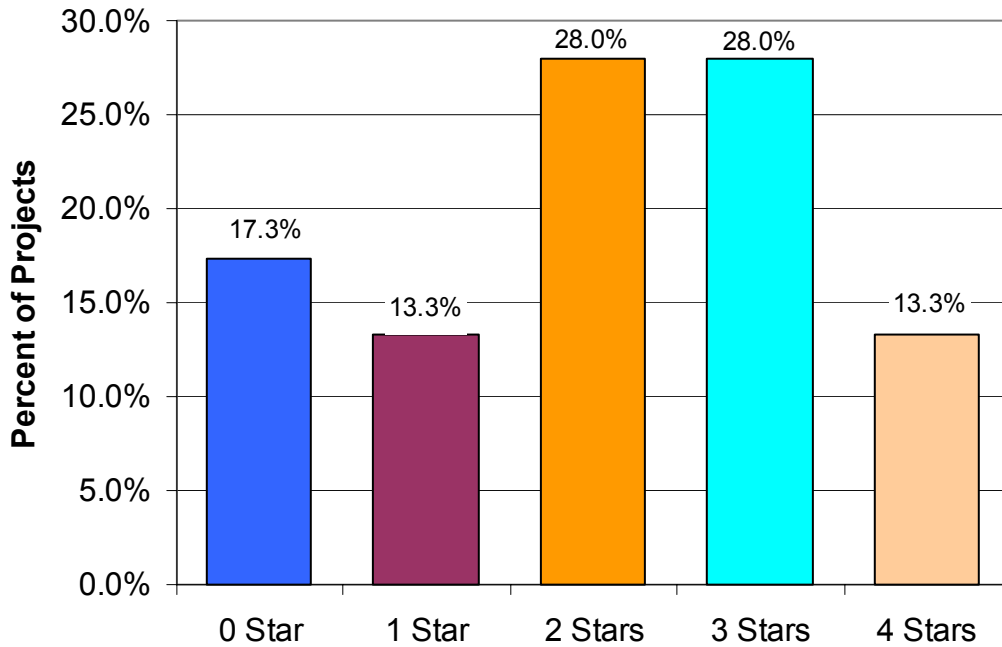
Source: Advanced Technology Program First 150 Status Reports

The 20 four-star projects overall include 16 single-applicant projects led by small companies and four joint ventures, two led by a consortium and two led by small companies. Leaders of these top-scoring projects are listed in Table 5-1.

Table 5-1
List of Four-star Projects

Aastrom Biosciences, Inc.	Nanophase Technologies Corporation
American Superconductor Corp.	National Center for Manufacturing Sciences (NCMS)
Automotive Composites Consortium (a Partnership of DaimlerChrysler [formerly Chrysler], Ford and General Motors)	Orchid BioSciences (formerly Molecular Tool, Inc. Alpha Center)
Cerner Corporation (formerly DataMedic - Clinical Information Advantages, Inc.)	SciComp, Inc.
ColorLink, Inc.	SDL, Inc. and Xerox Corporation
Cree Research, Inc.	Third Wave Technologies, Inc.
Engineering Animation, Inc.	Tissue Engineering, Inc.
Integra LifeSciences	Torrent Systems, Inc. (formerly Applied Parallel Technologies, Inc.)
Kopin Corporation	Xerox Palo Alto Research Center
Large Scale Biology Corporation (formerly Large Scale Proteomics Corporation)	X-Ray Optical Systems (XOS), Inc.

The three-star projects included 35 single-applicant projects and 7 joint-venture projects. Of the single-applicant projects, 25 were led by small companies, two by medium companies, and eight by large companies. Of the joint ventures, two were led by small companies, two by an industry consortium, two by a large company, and one by a nonprofit organization.

A few projects with low CPRS ratings had impressive technical achievements as indicated by the receipt of a third-party technical award, though most of the technical awards went to those with the highest overall ratings. In contrast, all of the awards for business acumen went to the projects with CPRS ratings of three or four stars

Performance by Technology Areas

Overall project performance in the intermediate period covered by the study varied by technology area, as illustrated in Figure 5-2. Of the 24 Biotechnology projects, 12 were three- or four-star projects. Of the 37 Electronics projects, half scored high. Of the 26 Manufacturing projects, close to third scored high, but 46 percent scored low. The 35 projects in the Advanced Materials and Chemical group were more evenly divided into high, low, and moderate scorers. The 28 Information Technology projects had 11 projects that were high-scoring projects, 7 moderate-scoring, and 10 low-scoring projects. Differences in life cycles among the technology areas may account for part of the performance differences, but the relatively small number of projects in each category does not support the drawing of robust conclusions about how projects in the different technology areas will perform.

Figure 5-2
Number of Composite Scores by Technology Area
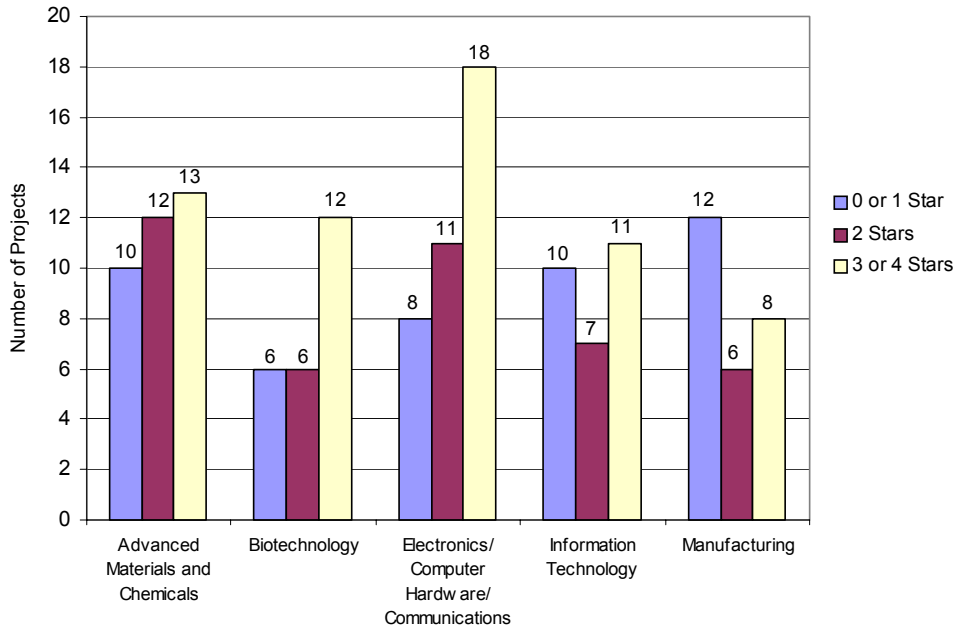
Source: Advanced Technology Program First 150 Status Reports

Project Performance Translated into Economic and National Security Benefits

Photonics

ATP has provided cost-sharing funding to more than 120 photonics projects since 1991[10]. To access the economic benefits from a portion of these projects, the author adopted a cluster study approach to combine the methodological advantages of detailed case studies and of higher level overview studies. The following five projects were selected for analysis: Capillary Optics for X-Ray focusing and Collimating; MEMS-Based Infrared Micro-Sensor for Gas Detection; Infrared Cavity Ring-Down Spectroscopy; Optical Maximum Entropy Verification; and Integrated Micro-Optical Systems.

Findings from the study indicate that U.S. industry and consumers, and the nation, will enjoy at least $33 of benefits for every dollar of ATP's $7.47 million investment in the cluster of five projects. ATP technology translates into $1.90 already realized benefits generated for every dollar of ATP's investment in the five projects.

Component-Based Software (CBS)

Developing the capacity to build large software systems from assemblies of smaller, reusable, independent components is an important strategy to reduce software system

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[10] Pelsoci, Thomas, M., *Photonics Technologies: Applications in Petroleum Refining, Building Controls, Emergency Medicine, and Industrial Materials Analysis*. NIST GCR 05-879 (Gaithersburg, MD: National Institute of Standards and Technology, September 2005).

costs, increase system reliability, and enable lower cost upgrades. Three projects included among the first 150 Status Reports were part of a portfolio of 24 projects that was included in an in-depth economic case study conducted by RTI.[11] These projects were led by **Reasoning Inc.**, **TopicalNet, Inc. (formerly Continuum Software)**, and **HyBrithms (formerly Hynomics Corp.)**.

Across the entire CBS portfolio, RTI's economic study estimated $840 million in net-present-value benefits and a benefit-to-cost ratio at 10.5, suggesting that the investment in the portfolio of projects as a whole was worthwhile. The net-benefits estimate is based on the cost of all 24 projects, but the benefits of only 8 were the subject of the detailed case study. In addition, the study found other benefits that were presented qualitatively, namely, enhancing the credibility of the mostly small software firms that were funded and assisting firms in strengthening their planning and management functions.

Reasoning Inc., TopicalNet Inc. (formerly Continuum Software), and Hynomics Corp. (formerly HyBrithms) had commercialization activities underway when RTI conducted its study. Their costs, but not their benefits, were included in RTI's aggregate portfolio net-benefit measure, because they were not among the eight projects selected by RTI for the portfolio benefits assessment. Thus, the RTI study results, at best, suggest that the three projects are part of a portfolio of projects found to be valuable. Of the three projects, two are rated as three-star performers, and one is a two-star performer.

It is also informative to look at how some of the other projects that were rated as top performers have progressed since the original data were compiled and the CPRS ratings calculated. Additional projects are profiled below.

Scalable Parallel Programming
One of the top-performing projects among the first 50 completed projects, originally profiled in Volume 1, was a project led by **Torrent Systems, Inc.** Although Torrent had fewer knowledge-dissemination outputs than the other top-performing projects, its exceptional commercialization efforts boosted it into the four-star group. The project developed a component software system that insulates programmers from the complexities of parallel programming while allowing them to use it productively in scalable applications. Torrent delivered this new capability in its software product, Orchestrate™. An early user of the new software, United Airlines, was able to increase its revenue by $100 million per year as a direct result of using Orchestrate™.[12]

When revisited in Status Reports, Volume 2, Torrent's technology was reported to be enabling e-businesses and other companies to process and analyze unlimited volumes of data. Torrent was listed in *Computerworld's* "100 Hot Emerging Companies" in 1998 and received a number of other awards recognizing both its software technology and business acumen.

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[11] White and Gallaher, November 2002.

[12] Information from Hoover's Online company search and Torrent's website, current August 31, 2000.

Since that time, Torrent, which had only two employees when it received its ATP award, has been acquired for a purchase price of $46 million by Ascential Software Corp., a global company with a market capitalization of $1.1 billion, headquartered in Westboro, Massachusetts.[13] According to Ascential's Chairman and CEO, Peter Gyenes, "Torrent's patented and proven parallel processing technology is a perfect complement to the rich feature set within our data integration solution, DataStage."[14] According to additional public statements by the company, Ascential has integrated Orchestrate™ into its DataStage XE product family, with the result that customers will be able to integrate data of virtually any volume and complexity, with infinite scalability, and turn growing amounts of data into valuable information assets.

United Airlines, first a Torrent customer and then an Ascential customer, is using Orchestrate™ and an IBM parallel-processing computer to design a system for managing airplane seat assignments. A statement by Bob Bongirno, managing director of applications development for United Airlines, which is posted at the Ascential Software Corp. website provides a user's perspective of the importance of the product:

> *"At United, we analyze 'astronomical' amounts of data every day through our Orion system to determine the optimum seat availability and price across tens of millions of passenger itineraries," he said. "For Orion and our other data-intensive applications, we demand a parallel processing technology that is robust and reliable enough to process massive data volumes on very large systems and will provide a state-of-the-art data integration foundation that helps us manage all our disparate data sources and accelerates the development of new applications. The combination of technologies from Torrent and Ascential holds great promise for meeting the data processing needs of customer-centric organizations like United."*

Thus the commercialization path has grown more complex for this ATP-funded technology as the technology has been combined with other software elements. At the same time, the impact potential of the technology appears strong. According to Doug Laney, META Group Vice President, the worldwide market for data integration was projected to grow from $900 million in 2001 to $1.3 billion in 2004,[15] and the technology platform funded in part by ATP appears well positioned to play a role in serving this growing market. Those projections were well-founded. Ascential grew rapidly in 2004, with a 46 percent increase in total revenue. In March 2005, Ascential agreed to be acquired by IBM for approximately $1.1 billion, strengthening IBM's fast-growing information integration business.[16] (Project number 94-06-0024)

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[13] Standard and Poor's stock report on Ascential Software Corp.

[14] Press Release, November 28, 2001, available on-line at www.ascentialsoftware.com, Press Center.

[15] Ibid.

[16] Company press release, "IBM to Acquire Ascential Software." March 14, 2005. (http://ibm.ascential.com/news/pr.html/view/1107)

High-Temperature Superconducting (HTS) Wire

The project led by **American Superconductor Corporation (AMSC)** is another of the top-rated 100 completed projects profiled originally in Status Report Volume 1. At the time Volume 1 was being written, the company was beginning to launch its commercialization effort. Since then, the company has reportedly continued making impressive advances, building the world's first high-volume HTS wire manufacturing plant with a capacity to manufacture 20,000 kilometers of wire per year when it is fully equipped. This new manufacturing capacity is said to give potential customers the ability to accelerate their schedules for launching commercial products incorporating HTS wire by making the product available to them in commercial quantities, at commercial prices.[17] AMSC's products and services listing now shows a vertically integrated portfolio that includes HTS wire, motors, generators, synchronous condensers, industrial power quality solutions, power conversion, and transmission grid solutions.

A press release issued October 1, 2003, announced that AMSC had received additional funding from the Department of Defense (DOD) and Department of Energy (DOE) to support further manufacturing scale-up for second-generation HTS wire. According to Dr. Paul Barnes, U.S. Air Force Superconductivity Team Leader, ensuring that the United States will have a reliable supply of the second-generation HTS wire is expected to be central to the development of many future military systems, including lightweight high-power generators and advanced weapon systems. According to James Daley, manager of the Superconductivity program at DOE, the technology is also expected to play an important future role in upgrading the nation's power grid.[18] (Project number 91-01-0146)

Visualization Software

As in the preceding examples, **Engineering Animation, Inc. (EAI)**, leader of another of the top-performing projects and originally profiled in Status Report Volume 1, continued to aggressively and successfully pursue applications of its award-winning imaging software capabilities developed in the ATP-funded project. Founded by two professors and two graduate students in 1990, EAI had 20 employees at the time ATP made the award. According to company officials, the ATP award allowed it to significantly extend its capabilities in computer visualization and computations dynamics and to form important collaborative relationships that enabled it to leverage the technology in many different directions. The company used its ATP-funded technology to improve the training of doctors as well as to guide medical procedures. Furthermore, patients reportedly had better outcomes when the visualization software was used during their surgical procedures.

In 1999, the company employed approximately 1,000 staff members and had sales of $71 million. At that time, EAI had extended and deployed its award-winning visualization

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[17] Information provided by the company at its website, www.amsuper.com.

[18] Company press release, October 1, 2003.

capabilities to develop a virtual factory technology implemented at Ford Motor Company. This application of the software enabled faster design and analysis of factory models.

On October 23, 2000, EAI was acquired by Unigraphics Solutions Inc. for $178 million. Subsequently, through acquisition and merger, Unigraphics and another software services company, SDRC, became a combined subsidiary of Electronic Data Systems Corporation (EDS), the world's largest information technology outsourcing services company, which has a worldwide infrastructure and 138,000 employees.[19] Unigraphics and SDRC were combined to form EDS's fifth line of business, Product Lifecycle Management (PLM) Solutions. This union provided, through Unigraphics NX software, a unified approach to extended enterprise collaborations enabling the modeling and validation of products and their production processes digitally from initial concept to finished parts. Thus, EAI followed the business model for growth of merging with a much larger company.[20] An online search revealed that previously developed EAI products and books remain on the market. (Project number 91-01-0184)

Examples of strong projects from among the three and four -star group are described below. These, too, appear to be delivering important economic benefits.

Improving Software Efficiency through Reusable Components
An example is a four-star project led by **Xerox Parc** which is credited with developing aspect-oriented programming (AOP) and later developed products that incorporated its principles. After the ATP funded project ended Xerox developed AspectJ, an open-source language based on AOP. Aspect J extends Java; and is being further developed and used in IBM's software applications and by many others. Eight patents emerged from this ATP-funded project and more than 3,250 articles or books have been written about AOP. In June 2003, AspectJ won the JavaWorld Editors' Choice Award for the Most Innovative Product or Technology Using Java. (Project number 94-06-0036)

Miniature LCSs Enhance High-Definition Displays
Another four-star project with continued strong commercialization was led by **Kopin Corporation**. Kopin formed a joint venture with Philips, and together with their subcontractor, Massachusetts Institute of Technology facilitated a paradigm shift in high-definition display technology. During the ATP funded project, Kopin and Philips combined existing monochrome liquid crystal displays (LCDs), with color, signal processing, and high-definition technology. Independently, Philips successfully commercialized high-resolution projection HDTVs using the ATP-funded technology. Kopin also successfully applied the ATP-funded enabling technology in numerous applications including miniaturized display applications for use in viewfinders for camcorders and digital cameras, wearable computers, virtual reality games, and military

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[19] Prior to the acquisition of Unigraphics, EDS was the major company stockholder. Information found at www.eds.com.

[20] Ibid.

applications. LCD projection display technology is a key product differentiator in U.S. electronics manufacturing. (Project number 94-01-0304)

Structural Composites for Large Automotive Parts
As a result of the ATP funded project the **Automotive Composites Consortium-ACC**, (A partnership of DaimlerChrysler [formerly Chrysler], Ford and General Motors) successfully produced a prototype box for a pickup truck that is stronger and more durable than steel, does not rust, is visually attractive, requires no bed liner, and improves fuel efficiency through its light weight (36 pounds, or 33 percent, lighter than steel). This pickup truck box gave the ACC member companies (General Motors [GM], Ford, and Chrysler, which later became DaimlerChrysler) the knowledge and tools to develop commercial products and to continue innovative research, based on this initial success. Applications of this successful ATP-funded technology include strong, lightweight components for aircraft, firefighter helmets, and marine motor covers. Project researchers shared their developments through one granted patent and several articles and presentations. As public acceptance of tough, durable composites increases, applications are expected to broaden. (Project number 92-01-0040)

To these examples, other promising technologies may be added—technologies that improve productivity, facilitate better weather forecasts, improve communications, enable new drug discovery, reduce energy costs, and improve health and safety.

What Difference Did ATP Make?

ATP aims to improve the international competitiveness of U.S. firms by funding projects that would not take place in the same timeframe, on the same scale, or with the same goals without ATP's support. A project may be successful in terms of achieving its goals, but if the same accomplishments would have occurred in the same timeframe without ATP, then the program has not had the intended effect. For this reason, evaluation studies of ATP—as well as other government programs—should apply the principle of "additionality" to correctly distinguish between benefits that would likely have occurred anyway and those benefits that are reasonably attributable to ATP.

In preparing the 150 individual mini-case studies, analysts asked project leaders about the role ATP funding played in their projects. Throughout the project selection process, beginning with the application, ATP presses the questions of why the project requires ATP funding, why funding is appropriate, what will happen if ATP funding is not provided, and how the expected outcome will differ with and without ATP involvement. During the evaluation process, these questions are again pursued retrospectively, i.e., what happened that was different as a result of ATP? Applied prospectively, the results are hypothetical. In evaluation studies, the results may be based on counterfactual survey and interview questions, such as those posed in the status report case studies. Evaluation studies have also used control group techniques, which provide more reliable evidence of the additional impacts of ATP.[21]

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[21] See *Survey of Applicants 2002*, NIST GCR 05-876, (Gaithersburg, MD: National Institute of Standards and Technology, June 2005).

Forty-six percent of the respondents indicated their projects would not have happened at all without ATP funding. Indeed, some participants said their companies would have gone out of business had the ATP award not been made.

Thirty-eight percent of the respondents said they would have attempted the project at some later date or at a slower pace and that ATP funding enabled them to accelerate the technology. Table 5-1 shows the project time savings attributed to ATP for those projects that reported they would have proceeded without ATP funding. With ATP, the projects avoided delays ranging from six months to five years and more. The acceleration of some of the projects may seem short; however, the value of even a small acceleration can be substantial. Speed in developing and commercializing a technology can also mean increased global market share for U.S. producers.

Table 5-2
Effect of ATP Funding on Expected Timing of Research

Effect on Project		Number of Projects
Would not have conducted Project without ATP funding		69
Would have proceeded without ATP funding, but with a delay*:		57
	Length of Delay	
	6 months	1	
	12 months	3	
	18 months	7	
	21 months	3	
	24 months or more	10	
	More than 5 years	11	
	Delay, but time unspecified	22	
No Response		24
Total		150

Source: Advanced Technology Program First 150 Status Reports

*Another factor potentially influenced by ATP funding (the scope and scale of the project) was not explicitly covered.

**The Printed Wiring Board Joint Venture project had a split response: half the tasks would not have been done at all and half would have been delayed by at least a year. This result is recorded conservatively in Table 5-1 as a two-year delay.

A number of companies also reported other effects of their ATP awards. Some reported that receiving their award enhanced their ability to raise additional capital. Some reported that their award helped them form collaborative relationships for research and commercial activities. Others reported that receipt of their ATP award had enabled them to gain in international competitiveness.

What Constitutes Success and Failure for ATP?

Because individual project failure must be allowed and tolerated in a program that focuses on overcoming challenging technical barriers to innovation, it is essential to take a portfolio approach to assessing ATP. Moreover, success should be assessed against the legislated mission of the program.

Four general tests, and several additional specific tests—all derived from ATP's mission—if applied after sufficient passage of time, should reveal the extent to which ATP has successfully met its mission, as described below.

Test 1: Has the portfolio of ATP-funded projects overall produced large net social benefits for the nation?

Test 2: Has a substantial share of net social benefits accrued to citizens and organizations beyond ATP direct award recipients?

Test 3: Did ATP make a substantial positive difference in the size and timing of the benefits?

Test 4: Has the portfolio of ATP-funded projects enhanced United States' economic and technological competitiveness?

Additional specific tests of success include the following: Did the projects produce new scientific and technical knowledge? Did ATP increase collaboration? Were small businesses able to participate? Were manufacturing capabilities improved?

While the ultimate answers to these success "test questions" depend on the long-run impacts of the entire portfolio of ATP projects, the performance-to-date of the sub-portfolio of 150 projects provides emerging answers.

There is mounting evidence that the tests for program success are being met. First, there is strong evidence that social benefits of the portfolio are large and exceed program costs. Second, there are benefits extending well beyond those captured by the direct award recipients: there is substantial evidence of knowledge and market spillovers as others cite the project patents and use the products. Third, there is evidence that ATP has made a significant difference in the amount and timing of benefits, as well as having other beneficial impacts on the companies. Fourth, there is some evidence of improvements in the competitiveness of U.S. companies.

The performance ratings show that the majority of the projects continued to make progress in the several years after ATP funding ended. Moreover, the portfolio has been shown to contain a core group of highly active and productive projects that are successfully accomplishing their high-risk project goals.

ATP awarded a total of $621 million to the 150 completed projects. Questions of keen interest are what is the public investment producing in the way of benefits, and are the tests for program success being met? Estimated benefits attributed to ATP from just a few of the 150 projects for which quantitative economic benefits have been provided exceed ATP's funding for all of the 150 projects. In addition, there is considerable evidence of large project benefits that have not yet been quantified.

This completes the portfolio view of ATP. Appendix A that follows provides an overview of the 150 individual projects that make up the portfolio. Appendix B describes reasons that some ATP-funded projects did not proceed to completion. Appendix C lists the first 150 completed projects along with their CPRS star ratings.

Accenture (formerly Andersen Consulting Center for Strategic Technology Research)

Software Component Integration:
An Architecture-Driven Approach

As early as the 1980s, experts had recognized that software developers could not keep pace with the demand for software products because of the increasing complexities of software systems development and maintenance. By the 1990s, the problem was critical. Although companies that marketed hardware were improving their products' capabilities for all kinds of tasks, the software could not keep up with these more complex tasks. Since many software tasks are repetitive, engineers turned their focus to developing software components that performed the same function over and over. These components were called "reusable software components." An individual component could perform a series of tasks to accomplish a data processing goal. This was similar to the way a reusable component called a "macro" in Microsoft Excel can replace a series of processing steps with just one keystroke.

The Andersen Consulting Center for Strategic Technology Research (CSTaR) proposed to develop reusable software components for business applications. As this complexity of the research made it very high risk, the company applied for and received Advanced Technology Program (ATP) cost-shared funding under the 1994 "Component Based Software" focused program and started research in 1995. The CSTaR researchers and their subcontractors sought to develop several new software specification languages for defining and integrating reusable software components.

The project faced several challenges. The key subcontractor, Expersoft, which provided expertise on software infrastructure, withdrew in 1996 due to changes in management and business goals. While Andersen Consulting completed most of their technical goals, they were never able to commercialize a product. The project suffered further from understaffing and turnover, especially after Expersoft withdrew. As of 2004, current approaches to software reuse for business applications have tended to focus on smaller and less complex components, rather than on the large components proposed by the CSTaR team.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)

No Stars

Research and data for Status Report 94-06-0012 were collected during September – November 2004.

Software Development Crisis Identified as Early as the 1980s

By the early 1980s, software applications were becoming more and more complex, and software engineers had to spend an inordinate amount of time on designing, testing, and debugging. By the 1990s, the problem had become critical. The industry was facing a serious shortage of skilled programmers who could meet the time-intensive demands of software development. In response to this problem, programmers suggested that the software's basic functions, which consist of a series of specific, repetitive tasks, could be packaged as reusable components. The construction of software systems from those components could then be automated, similar to the way a macro in Microsoft Excel executes a multi-step task through just one keystroke. For example, a specific application of component reuse would be when the programming steps necessary to automate the task of

withdrawing money from a bank account are packaged as a reusable component. That component could be reused by several applications; for example, by the bank teller or by the account holder via a home personal computer. Also, developing a timesaving "reusable component system," also called a library, would help to alleviate the shortage of U.S. programming personnel.

Software architecture describes how components can be assembled to ensure that the components' interfaces are sound as they work together. One company that wanted to design software architecture was the Andersen Consulting Center for Strategic Technology Research (CSTaR). A division of Andersen Consulting, the CSTaR group planned to develop several software specification languages to describe and assemble the components to work together. For all players in the software component reuse industry, the challenge of architecture and component design was very high risk due to the extreme complexity involved. For example, the architecture must enable component users to correctly select and combine components without having to be familiar with the components, or even with the details of the programming languages. Furthermore, generic software tools to do this did not exist in 1994 when the project was first proposed. Based on these challenging technical conditions, Andersen Consulting applied for and received cost-shared ATP funding to develop the architecture under the "Component Based Software" focused program of 1994 (the project started in 1995).

Reusable Software Components Would Provide Benefits

If the project achieved its goals, the expected benefits to the U.S. economy would include enabling quicker development of new software by reusing components, thus freeing programming personnel for other tasks. This could be achieved by maximizing the reuse of software rather than performing wasteful software re-designs on repetitive functions. Fewer software engineers would be needed to develop and maintain complex software systems, which would help reduce the cost of both complex software system development and maintenance. Also, technology spillovers could potentially apply to all industries that performed

repetitive data processing tasks, such as insurance, retail, travel, and state and Federal Government agencies.

Software Reusability in the 1990s Was Limited

Before Andersen Consulting's approach to the systematic integration of software components could be automated, several new programming languages needed to be developed and tested so the components would work together correctly. According to Jim Ning of the CSTaR team, in the mid-1990s, software component architecture design software had not progressed much in functional and technical requirements for the architecture languages. This meant that the exact functions of the components and the supporting technical libraries for them were not fully developed. Architecture advances were needed to facilitate system configuration and the interfacing between components. The industry at the time had achieved useful architecture modeling only on such issues as high-level business modeling, on representation of business entities and activities, and on low-level design and code generation. The CSTaR team envisioned developing a few large components in its new reusable software architecture rather than many smaller components. This way, the number of required components would be small, and the architecture could be relatively simple compared to a large, unwieldy library of smaller components. The original project goals were to accomplish the following:

- Add a capability to the component architecture to create a reusable software component library for Andersen Consulting's client service base for generic business applications

- License the product through Expersoft

- Add tools or technology to the development and integration services that Andersen Consulting offered its clients

CSTaR Develops New Programming Languages

After completing the component reuse library, CSTaR hoped to assemble task-specific software systems from components in the library by using a graphical user

interface on a PC. Each software component would include descriptions of its own semantic considerations. Semantics considers whether the software input data agree with the output data; that is, is the output reasonable when considering the input? Most, but not all, of the individual component designs for performing each component function listed below were completed by project end (see list below for specifics on completion). Several of the component functions are summarized below. Each language needed development.

- **Architecture Specification Language (ASL)**. Developers would use this language to describe how software defined the architecture of all components. The architecture required developing the following three sub-languages:

  - *Interface Specification Language (ISL)*. Developers would use this language to specify the component interfaces. ISL is a semantic extension of the "object-oriented" interface definition language. (Object-oriented means that data, and operations that are performed on that data, are "encapsulated" as an independent operation that is not dependent on any external requirement for the operation to be performed.) This kind of operation can be considered an "object." When software displays a bank account balance, for example, the balance is considered an object. This object consists of data, such as current balance, and history information such as deposit and withdrawal amounts.

  - *Glue Specification Language (GSL)*. This language was an extension to the ISL that enabled developers to specify composition, adaptation, and coordination among components.

  - *Configuration Specification Language (CSL)*. This language was an extension to the ISL and GSL that enabled developers to specify the configuration of software components to different computer operating systems.

- **Specification Verification and Analysis (SVA) Language**. This language enabled developers to specify the mechanism for verifying, analyzing, and implementing the ISL, GSL, and CSL. The

purpose of the SVA language was to ensure that only compatible components would be interfaced to work together. If two components did not work together easily, the SVA language would generate adaptors for noncompatible interfaces. The designers completed a prototype, but determined by the end of the project that more testing and usability evaluation would be necessary to perfect the design.

- **Packaging Technology (PT) Language Subsystem**. This language, and its associated subsystem for implementing the language, transforms ISL, GSL, and CSL specifications into compilation and configuration procedures for code generation. As with the SVA language, the designers completed a prototype for this component, but they determined by the end of the project that more testing and evaluation were needed.

- **Reuse Library Technology (RLT) Subsystem**. This subsystem would be a versatile classification-based reusable component library system. Users would access the library through the Internet, which would provide many users simultaneous access to whatever components were needed. The CSTaR team completed a prototype library, but the library was not ready to integrate with the architecture design by the project's conclusion.

- **Architecture Design Environment (ADE)**. This subsystem was the visual design environment in which the ISL, GSL, and CSL were graphically represented. A prototype was completed and usability testing and initial testing were performed; however, more testing was needed after project completion.

- **Domain Analysis and Application Development (DAAD)**. This subsystem was an application system to evaluate and demonstrate the research deliverables. A prototype banking application was developed, but due to the lack of resources and staff, a larger scale test could not be done.

CSTaR Creates An Alliance to Develop Tools

To help achieve their technical and commercialization goals, Andersen Consulting partnered with

subcontractors Expersoft, a professor at the University of Maryland, and CoGenTex to achieve their project goals. Highlights of each subcontractor's participation in the ATP-funded project are provided below:

- Expersoft, a small software business, was chosen based on its successful development of XShell, a distributed object management (DOM) tool for large organizations. A DOM tool allows network functions, such as decision-making and file storage management, to be performed from several distributed locations throughout a network. Use of a DOM tool is more efficient than performing such functions from a centralized location in the network. XShell as a DOM tool pre-dated the Object Management Group's (OMG) common object request broker architecture (CORBA) standard. The OMG is a standards consortium that produces and maintains computer industry specifications for specific programming applications that must interoperate with each other. Since software components perform applications, the project developers wanted to use the best practices as discovered by OMG members. This standard sought to create a common interoperable platform for hardware and software vendors to support object interaction. After the CORBA standard was published, Expersoft committed to implementing it. (Andersen Consulting and Expersoft were voting members of the OMG.) Andersen Consulting assigned Expersoft to configuration-language- and packaging-language-related tasks in a network environment, where the packaging language provided the executable code for components when they were run.

- Professor James Purtilo of the University of Maryland, a senior member of the Institute of Electrical and Electronic Engineering (IEEE), was a published expert in specification languages. He assisted with several technical goals, such as the PT language. Purtilo had demonstrated that an "inference engine" could be successfully incorporated with a packaging component. The inference engine, as the name implies, could make judgments about the compatibility of software components.

- CoGenTex was a small business specializing in the automatic translation of computer language to paraphrasing in natural (English-like) language, an expertise that the CSTaR team needed in order to facilitate component use by component end-users. An example of natural language would be, "Step 3 retrieves data from location A, processes it, and stores the result in location B." (The same statement expressed in computer language would be a highly formatted mixture of alphabetic, numeric, and symbol character displays that has no resemblance to standard English.) CoGenTex had previously collaborated with Andersen Consulting's Foundation Development Group, a division of Andersen Consulting that provided customized software solutions for clients.

Subcontractor Changes Impede Progress Toward Goals

Although the project team demonstrated a prototype system each year during the two-year project, none of the prototypes developed into a product that could be commercialized. In May 1996, about midway through the project, Expersoft came under new management that decided to refocus the company's business goals on platform tools for the object-oriented operating system market, rather than on object-oriented software development. The company therefore withdrew from the project. This subsequently caused a scheduling delay in the development of the PT language, one of the more important technical goals. Consequently, that language was not developed beyond the prototype stage. DHR Technologies, a firm specializing in networking services, then assumed the commercialization effort formerly spearheaded by Expersoft. However, DHR did not make any significant progress on product development. Andersen Consulting pursued other partners, including some large software tool vendors and small startups, but without success.

Other factors impeded the achievement of the team's technical goals. These included underestimation of the complexity of the tasks involved, understaffing and staff changes at Expersoft, and the late start of key personnel on the project work.

One of CSTaR's developers, Francois Bronsard, stated at the conclusion of the project that formal specifications are difficult to write for large, complicated components. He acknowledged that by the project's end more developmental work was still needed on the communication layers in the architecture, due to unforeseen difficulties that developed. Further development on all project technology stopped after the conclusion of the project. The project researchers produced nine journal articles and seven conference presentations, which included prototype demonstrations. Two years after the project concluded, Vertel acquired Expersoft.

As of 2004, the CSTaR team's approach to large-scale reusable software components is out of favor in the industry. Developers now rely on templates and object-based software that focus on simpler, smaller components. Due to this shift in industry focus from complex to simpler components, the CSTaR team realigned their goals accordingly.

Conclusion

In the 1980s and 1990s, the accelerating need for complex software systems development spurred the demand for reusable software components in order to reduce development cost and time. By the 1990s, software engineers recognized that new languages needed to be developed to enable a new concept in programming, called "components," to work together as a system. Andersen Consulting Center for Strategic Technology Research (CSTaR) teamed with subcontractors Expersoft, CoGenTex, and James Purtilo, a professor in the University of Maryland's Computer Science Department, to create a component system.

Although the team developed a few prototypes and presented them at software development conferences, the project did not result in commercialization, and no companies were attracted to develop a product. Late in the project, the principal subcontractor, Expersoft, withdrew after new management changed the company's business goals. Although the remaining subcontractors contributed to the development of some of the languages needed for the reusable software component architecture, none wanted to further commit capital to develop a product. Advances in object-oriented programming both before and during the project overtook the large component design that was popular during the project period. Subsequently, Andersen Consulting abandoned the technology to refocus on other business goals. The team shared their project research through nine publications and seven conference presentations.

PROJECT HIGHLIGHTS
Accenture (formerly Andersen Consulting Center for Strategic Technology Research)

Project Title: Software Component Integration: An Architecture-Driven Approach

Project: To develop a prototype technology for reusable software components based on software architecture considerations, including formal languages to express semantics, a graphical user interface programming environment, automated techniques for assuring that the separate components are logically compatible and properly combined, and automated systems to generate executable systems.

Duration: 3/1/1995–2/28/1997
ATP Number: 94-06-0012

Funding(in thousands):**

ATP Final Cost	$1,432	93%
Participant Final Cost	108	7%
Total	$1,540	

Accomplishments: With ATP funding, Andersen Consulting developed several prototype languages. The company shared their project knowledge in nine publications and at seven conference or workshop presentations (listed at the end of the report).

Commercialization Status: No product was commercialized as the technology focus of the industry changed shortly after the project concluded.

Outlook: The outlook for this technology is weak due to the industry shifting its preference to the more easily managed challenges of smaller, less complicated components.

Composite Performance Score: No Stars

Focused Program: Component Based Software, 1994

Company:
Accenture
161 North Clark Street
Chicago, IL 60601

Contact: Jim Q. Ning
Phone: (312) 693-3830

Subcontractors:

- Expersoft
  Woodland Hills, CA
  (Expersoft is no longer in existence; Vertel acquired the company in 1999)

- CoGenTex Inc.
  Ithaca, NY

- James M. Purtilo
  Department of Computer Science
  University of Maryland
  College Park, MD

Publications: Researchers shared their findings in the following publications:

- "Component-Based Software Engineering," Andersen Consulting, internal publication, 30-page white paper, February 1995.

- "Component Integration Specification," *Proceedings of ICSE Workshop on Architectures for Software Systems*, Seattle, WA, April 24-25, 1995.

- "Architecture Specification Support for Component Integration," *Proceedings of the Seventh International Workshop on CASE*, Toronto, Canada, July 10-14, 1995.

- "Exactness and Clarity in a Component-Based Specification Language," Book chapter in *Specification of Behavioral Semantics in Object-Oriented Information Modeling*, Kluwer Academic Publishers, 1996.

- "Concern-Driven Design for a Specification Language Supporting Component-Based Software Engineering," *Proceedings of the Eighth International Workshop on Software Specification and Design*, Schloss Velen, Germany, March 22-23, 1996.

- "On the Need for Required Interfaces of Components," 10th European Conference on Object Oriented Programming (ECOOP'96) Workshop on OOP, Linz, Austria, July 8-12, 1996.

- "A Component-Based Software Development Model," *Proceedings of the Twentieth Annual International Computer Software and Applications Conference*, Seoul, Korea, August 19-23, 1996.

PROJECT HIGHLIGHTS
Accenture (formerly Andersen Consulting Center for Strategic Technology Research)

- "Where does Architecture Research Meet Practice?", *Proceedings of the Second International Software Architecture Workshop*, San Francisco, CA, Oct. 14-15, 1996.

- "Toward Software Plug-and-Play, Symposium on Software Reusability," in conjunction with the International Conference on Software Engineering (ICSE 97), Boston, MA, May 18-23, 1997.

Presentations: The project team shared at several workshops and conferences:

- "Concerns of a Reusable Assets Broker," Workshop on Software Reuse, St. Charles, IL, 1995.

- "Component-Based Software Engineering," Workshop CASE'95, Toronto, Canada, July 10-14, 1995.

- "ADE - An Architecture Design Environment," demonstration at the Fourth International Conference on Software Reuse, Orlando, FL, April 23-26, 1996.

- "Panel on Component-Based Software Engineering," Fourth International Conference on Software Reuse, Orlando, FL, April 23-26, 1996.

- "Panel on Roles of Architectures in the Development of Software Systems," The Twentieth Annual International Computer Software and Applications Conference, Seoul, Korea, Aug. 21-23, 1996.

- "Panel on Reengineering Infrastructure," The Third Working Conference on Reverse Engineering, Monterey, CA, Nov. 8-10, 1996.

- "ADE - An Architecture Design Environment for Component-Based Software Engineering," presented at ICSE 97, Boston, MA, May 18-23,1997.

Research and data for Status Report 94-06-0012 were collected during September – November 2004.

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Cerner Corporation

Methodologies for Automating Clinical Practice Guidelines

In 1991, healthcare expenditures in the United States were more than $700 billion. Participants in the U.S. healthcare system, from patient to payer, recognized the importance of decreasing the cost of healthcare while improving its quality.

One initiative was the development of clinical guidelines, which many government agencies had undertaken. The guidelines incorporate best practices that address many different medical situations and have the potential to eliminate variations in treatment and the use of inappropriate procedures. Yet, by 1994, the guidelines were still used infrequently, in part because they were printed in thick handbooks, which made it difficult to quickly find information. Moreover, the guidelines were often too general for clinicians to use in specific situations.

Cerner Corporation, a leading U.S. provider of clinical and management information systems, planned to increase clinical guideline usage. Cerner estimated that if optimized clinical guidelines existed for almost all serious conditions and were implemented on a large scale in tools readily available in clinical practice, the United States could ultimately save billions of dollars in healthcare costs each year, while improving the quality of care. To increase the use of clinical guidelines, Cerner proposed to develop information tools, in collaboration with the University of Alabama at Birmingham and the Columbia-Presbyterian Medical Center. These tools would automate, validate, and distribute the guidelines for mass use. In 1994, as part of a focused program called "Information Infrastructure for Healthcare," Cerner received an award from the Advanced Technology Program (ATP) for a three-year project that began in 1995.

By the end of the project in 1997, Cerner had successfully developed information tools and a process for providing automated clinical guidelines to clinicians. However, the company was unable to commercialize the new technology after finding that clinicians were resistant to using the computer during the clinical process. Cerner has successfully used general concepts from the ATP-funded project to execute guidelines in its Cerner Millennium product. With Cerner Millennium, clinicians are electronically alerted about potential patient safety and regulatory issues through evidence-based medical information.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)

No Stars

Research and data for Status Report 94-04-0008 were collected during October 2003 – February 2004.

Clinical Practice Guidelines Are Infrequently Used

Clinical practice guidelines, which are carefully developed statements that incorporate the best practices in healthcare, can assist healthcare practitioners in making decisions on appropriate care for patients in specific clinical circumstances. The guidelines have great potential to improve the quality of care by providing clinicians with current information that can be useful in many medical situations and by reducing variations in treatment and the use of inappropriate procedures. However, despite these benefits, clinical guidelines were infrequently used in the mid-1990s.

At that time, the guidelines were published in thick handbooks and were distributed to clinicians or were communicated through phone calls from case workers, commonly known in the health field as utilization reviewers. This made it difficult for the clinician to access relevant information at the time it was needed. Furthermore, the guidelines were often too general to apply to specific medical situations and, for the most part, had not been evaluated for their effect on patient treatment or acceptance by clinicians.

New Technology Could Automate Guidelines

Cerner Corporation, a leading provider of clinical and management information systems in the United States, recognized that in order to be useful, clinical guidelines had to be (1) available to the clinician when he or she was making a decision about a patient's treatment; (2) delivered within an integrated computer system; (3) applied to a patient's specific medical condition and associated with a clear, recommended course of action; and (4) evaluated for the results they produced and their acceptability to clinicians. According to Scott Siemers of Cerner, "The idea was to deliver the right information at the right time." To increase the use of clinical guidelines, Cerner proposed to develop an information infrastructure that would include the following:

- Methods for transferring written guidelines first to expert systems (software applications using a knowledge base of human expertise to aid in solving problems) then to healthcare professionals

- An effective computer-based architecture for implementing guidelines into a clinical practice. The system would be able to take guideline data and use it to provide to the clinician custom strategies and alternatives that were based on a specific patient's medical condition

- New coding structures that would package guidelines in automated, decision-support tools for use in different locations and situations

- Methods for testing the effectiveness of a guideline on practice patterns, quality of patient care, its safety, and its acceptability to clinicians

- A model for collecting and standardizing data from different systems, which would make it possible to evaluate and compare alternative treatments and interventions

At the same time that it developed the information infrastructure, Cerner would also develop guidelines for the new system. The company would identify topics that it believed could significantly improve laboratory medicine, would review and revise the written guidelines, would encode the guidelines, and would then deploy them in clinical practice. Finally, Cerner would evaluate the effectiveness of the guidelines and the deployment methodology.

Cerner believed that these changes would make a significant impact on the healthcare field. The infrastructure would include dynamic decision-support tools, which would lead to rational, repeatable medical care that could be evaluated. In the beginning of the project, Cerner would work only with laboratory medicine guidelines, but the methods could later be extended to other clinical domains.

Cerner Anticipates Broad-Based Benefits

Cerner believed that automated clinical guidelines had the potential to significantly improve healthcare in the United States. As guidelines became easier to access and apply to medical situations, they would be used more frequently, resulting in more standardized care based upon best practices. Moreover, the cost of healthcare would decrease as the number of hospital stays and complication rates declined and the morbidity and mortality rates decreased. The company estimated that if clinical guidelines were implemented on a large scale, savings in U.S. healthcare costs could amount to tens of billions of dollars per year.

Development of Automation Tool Suite Poses High Risk

Cerner understood that developing information tools and methodologies for automating, validating, and mass-distributing clinical practice guidelines was a high-risk endeavor. Introducing new technologies for automating standard guidelines into clinical settings would require meeting several technical challenges, such as determining how to build an infrastructure that could express certain elements of guidelines, like event sequences and flow charts, so that they could be used

by an expert system. Another challenge would be to identify the events that would trigger rule processing and the data elements needed for rule execution.

Because the project risks were more than Cerner could assume at the time, the company sought financial support from ATP in 1994. In the beginning of 1995, three-year funding was awarded as part of the ATP focused program, "Information Infrastructure for Healthcare." This support would allow the company to work to achieve all of its project objectives and would give Cerner the opportunity to ultimately commercialize the software and knowledge modules needed to automate clinical guidelines.

To obtain critical medical expertise, Cerner would collaborate with the University of Alabama at Birmingham (UAB) and the Columbia-Presbyterian Medical Center (CPMC). UAB would perform needs assessments and evaluations and would work with Cerner to select and evaluate implemented guidelines. CPMC had extensive experience creating medical logic modules for critiquing clinical practices and had led national efforts to introduce standard medical dictionaries, to transfer medical logic modules, and to encode guidelines. CPMC would provide a second evaluation site.

Cerner Develops New Technology for Automating Clinical Guidelines

Cerner's approach to meeting its goal of developing methodologies for automating, validating, and mass-distributing clinical practice guidelines followed a structured process. During the first year of the ATP-funded project, the company selected high-value guideline topics. For example, Cerner determined that blood transfusion and antibiotic selection presented good opportunities to make improvements. To clarify these topics further, the company focused on (1) the prevention of adverse events (this would improve patient care quality and reduce costs); and (2) order substitution (cases when a medication that is as effective and safe as another, but less expensive, could be substituted).

Next, Cerner developed a structure for presenting the guidelines to the clinician on the computer screen. The message would be displayed to the clinician in bullet style that used the fewest possible words. (Based on a customer concept test, the company believed that the message would have to be short and focused in order to gain a physician's attention and encourage him or her to use the guideline.) The message structure would also permit queries, would suggest alternative actions, would provide hypertext explanations, and would allow the clinician to customize it. The guideline would also be delivered to the physician within one second of placing the order for a drug or procedure. Cerner believed that the guideline would have the greatest impact at this point.

Cerner believed that automated clinical guidelines had the potential to significantly improve healthcare in the United States.

By the end of the first year, Cerner had developed a prototype for a guideline product, Order Pro. It then formed an engineering team to develop solutions that would enable its already existing medical expert system, Discern Expert, to function with Order Pro and with the software used by physicians when placing an order for a drug or procedure.

In the second year of the project, Cerner focused on developing a consistent, high-quality process for authoring, reviewing, and disseminating the guidelines (now called "alerts," a name selected by Cerner to describe the cautionary nature of the guideline message). The company had learned in the previous year, through repeated trial and error, how difficult it was to write alerts. The alerts must significantly improve care delivery, and they must be specific enough to be encoded in a computer system. To assist with writing alerts, the company developed an author style guide, which it believed would set a new standard for knowledge transfer. The guide provided information on creating interactive alerts, actionable suggestions, and hypertext explanations. The company also worked to develop an internal and external peer review process for completed alerts that would meet the Food and Drug Administration's requirement for good manufacturing practices. Cerner decided to partner with Adis, a leading-edge New Zealand medical publishing company specializing in pharmacotherapy and pharmacoeconomics. Adis had the research and review mechanisms to create and update high-quality written materials. Adis also had an understanding of new markets and business processes, which would benefit Cerner.

Cerner created several prototypes of its new product. The first prototype, version 1.0, was completed in October 1996 and included the following features:

- Message display
- Interactive queries to narrow the context of an alert
- Selection of orders, with a recommendation that could easily be transferred to an order pad
- Ability to transfer information, regarding the action a physician took in response to an alert, to an action-tracking activity table

Engineering Problems with Second Prototype Delay Release

Cerner experienced significant engineering problems with the next prototype, version 1.1, and its release was delayed. This version included more complex features, such as the ability to trigger an alert from a laboratory order, forward a message to a clinician who was not logged into the system, recall the results of previous queries, and develop several action-tracking reports.

During the second year of the ATP project, Cerner worked on its marketing plan, which the company funded itself. Moreover, the company began to share its project-related knowledge with others in the healthcare field. Cerner spoke to the medical faculty at the Medical Center of Delaware about the company's efforts to develop and implement clinical guidelines for managing care. Presentations were also made to the MidWest Managed Health Care Congress about developing information management strategies to improve the delivery of patient care.

The alerts must significantly improve care delivery, and they must be specific enough to be encoded in a computer system.

By the third and final year of the ATP-funded project, Cerner had modified its goal to complete 100 Insights to completing 30. (Insights were previously called "alerts"; the name was changed to make the technology more appealing to physicians.) The company revised its goal because of both the complexity of writing each Insight and the high cost, which was estimated at between $20,000 to $30,000 for each Insight. One difficulty the company encountered was managing the number of exceptions to each Insight. Cerner found that the

number of exceptions increased the more the Insight was studied.

Cerner continued to build tools for clients that might want to create their own Insights. The company also completed a prototype of Discern Dialogue, an application that would enable a clinician to query the system about information delivered through an Insight. The prototype included functionality such as triggers for patient admissions, patient relocations, and laboratory results.

Clinicians Were Reluctant to Use New Technology

By the end of the ATP-funded project in 1997, Cerner had successfully developed an automated process for delivering clinical guidelines to healthcare professionals and, through several prototypes, had demonstrated that the process would work. The company planned to commercialize its new technology by licensing knowledge modules (50 to 75 Insights in a specific domain of medicine, such as drug-lab interactions or antibiotic utilization) on a subscription basis, for use within Cerner software systems.

To prepare for commercialization, the company conducted extensive market analyses, completed a business plan, pursued several technical and business alliances, prepared a market survey, showed its product concept to several potential clients, and trained its sales force. The company also gave several presentations on the new technology.

However, despite its marketing efforts, Cerner was unable to commercialize the new technology. Although the technology seemed promising to hospitals, many clinicians rejected the idea of using computers during the clinical process. They viewed the computer as an administrative device that would slow the clinical process.

ATP-Funded Project Results in Benefits

As of 2004, Cerner had not commercialized the technology it developed for automating clinical guidelines; however, the company had applied generalized concepts from this technology to implement Zynx guidelines and other evidence-based guidelines in the Cerner Millennium solutions. This solution integrates evidence-based content developed by Zynx Health (a former subsidiary of Cerner that evaluates

current scientific data) into an architecture used to structure, direct, and maintain clinical content as executable knowledge. Zynx has an extensive library of clinical "rules" and supporting evidence-based information regarding patient safety and regulatory compliance. This knowledge is used with an expert rules engine to electronically inform and alert clinicians about potential patient safety and regulatory issues. The solution is licensed to hospitals. In March 2004, Zynx Health was acquired by the Hearst Corporation.

Conclusion

With ATP's assistance, Cerner developed information tools, medical content, and a process that could be used to provide best practices in healthcare to clinicians through automated clinical practice guidelines. At the end of the project, however, Cerner found that clinicians were reluctant to use computers, which they associated with administrative tasks, during the clinical process. Thus, the company was unable to commercialize the new technology. Since then, Cerner has successfully used general concepts from the ATP-funded project to execute guidelines in its Cerner Millennium product. With Cerner Millennium, clinicians are electronically alerted about potential patient safety and regulatory issues through evidence-based medical information.

PROJECT HIGHLIGHTS
Cerner Corporation

Project Title: Methodologies for Automating Clinical Practice Guidelines

Project: To develop information tools that automate, validate, and distribute clinical practice guidelines for clinician use.

Duration: 1/1/95-12/31/97
ATP Number: 94-04-0008

Funding (in thousands):

ATP Final Cost	$1,720	90%
Participant Final Cost	193	10%
Total	$1,913	

Accomplishments: ATP funding enabled Cerner to develop the technology to provide automated clinical practice guidelines to clinicians while they were providing treatment to a patient. Using this technology, clinicians could make informed decisions about appropriate healthcare for a patient based on his or her condition, history, and the best recommended practices. In addition to message display, the technology included features such as interactive queries, alerts to a clinician based on a laboratory order, and action-tracking reports.

Cerner shared its project-related knowledge through the following publications and presentations:

- Cerner Annual Healthcare Conference. 1995, 1996, and 1997. (Presentations).

- Jamieson, Patrick, M.D. "Computer and Information Technology in the Health Field." Conference Presentation, Saudi Arabia, 1995.

- Jamieson, Patrick, M.D. "Developing and implementing clinical guidelines for managing care." Speech to Medical Center of Delaware, 1996.

- Jamieson, Patrick, M.D. "Developing information management strategies to improve the delivery of patient care." Speech to Midwest Managed Health Care Congress, 1996.

- Healthcare Information and Management Systems Society Conference, 1997 (Presentation).

- Healthcare Information and Management Systems Society Conference Proceedings, 1997 (Publication).

Commercialization Status: Cerner did not commercialize its technology for automating clinical practice guidelines. In 1997, when the ATP-funded project ended, clinicians were reluctant to use computers during the clinical process. In 1998 and 1999, hospitals were focused on meeting Year 2000 requirements and did not want to implement new technology. Cerner continued its marketing efforts until after 2001, but was not successful. However, the company has since been able to apply the knowledge it gained from the ATP-funded project to its Cerner Millennium solution, an automated medical information system that alerts clinicians about potential patient safety and regulatory issues.

Outlook: Since 1997, other companies, such as IDX Systems, 3M, and Eclipsys, have been using technology similar to that developed by Cerner for automating clinical practice guidelines. These technologies include features such as order entry and insights. As of 2004, Cerner plans to use general concepts from the ATP-funded project to execute guidelines in its Cerner Millennium product.

Composite Performance Score: No Stars

Focused Program: Information Infrastructure for Healthcare, 1994

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Cerner Corporation
(formerly DataMedic–Clinical Information Advantages, Inc.)

Coding and Storing Patient Information with MEDencode

Beginning in the 1980s, the demand for detailed patient information began to increase as clinicians sought more information in order to provide better patient care. Healthcare payers also wanted to gather more information so they could assess the effectiveness of patient care and better control costs. The primary source of patient information was the clinical note; however, important facts, such as the severity of a patient's illness, were often left out. To assist in gathering more complete patient information, Clinical Information Advantages, Inc. (CIAI), a clinical software company and subsidiary of DataMedic Corporation, proposed to adapt its existing notewriting technology to a knowledge-base-driven automated coding system. This system would make it easier for clinicians to generate detailed and complete clinical notes. CIAI believed that the new technology would significantly enhance the effectiveness of providers and, if widely adopted, could result in annual healthcare savings of $2 billion.

In 1994, DataMedic received an award from the Advanced Technology Program's (ATP) focused program, "Information Infrastructure for Healthcare," for a three-year project. Although the company was unable to incorporate the new technology into its electronic medical record product, CHARTstation, during the ATP-funded project, it successfully developed a software component called CHARTnote that could be used with CHARTstation, as well as with other products. CHARTnote utilizes MEDencode, a new technology developed over the course of the project, which automatically gathers, codifies, and records specific, detailed information about a patient.

By the end of the project in 1997, CIAI had successfully commercialized CHARTnote for gastrointestinal endoscopy. By 2000, thousands of clinicians were using the software to write clinical notes. In 2004, the company (now a division of Cerner Corporation) offered approximately seven CHARTstation products in different medical areas that incorporate the MEDencode technology. The ATP-funded project also resulted in several publications and presentations.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 94-04-0038 were collected during May – August 2004.

Clinicians and Healthcare Payers Seek More Complete Patient Information

Beginning in the early 1980s, both clinicians and healthcare payers sought more detailed patient information. Clinicians wanted more data on their patients' clinical histories so they could provide better care. Healthcare payers, such as health maintenance organizations, wanted more detailed information from clinicians about their patients and the outcomes of treatment so they could better manage costs. These data were being used to compare clinicians based on their costs, their compliance with practice guidelines, and the outcomes of their care. Payers could then make informed decisions about providers with whom to contract, provide information to patients and the public on the quality of care offered by providers, and assist providers in improving the quality of their care.

The clinical record, the primary source of patient information, was being used to evaluate provider performance. Yet, many records lacked the detail necessary to make a valid comparison of clinicians and the care they provided. It was determined that the primary reasons for this were the following:

- Significant patient information, such as the severity of a patient's illness, was not being recorded by clinicians.

- There was often reluctance on the part of clinicians to use the computer (especially those who felt comfortable using the dictaphone, which is a less structured means of recording patient notes).

- Many clinical information systems were capable of capturing only a limited amount of data.

MEDencode Technology Could Simplify Collection of Patient Information

Clinical Information Advantages, Inc. (CIAI), a subsidiary of DataMedic Corporation, designed and developed electronic medical record systems for clinical practices. The company wanted to assist clinicians by simplifying the process of collecting detailed patient information. CIAI proposed to develop technology called MEDencode that would automatically gather, codify, and record specific, detailed information about a patient. The information would be automatically saved in a computer-based patient record (CPR) during the clinical notewriting process. With the MEDencode technology, key terms such as symptoms and age would be captured in the CPR as the clinician completed it, leading to a diagnosis of the patient's condition and a descriptive report. At the same time, the coded data would be integrated into a database where it could later be accessed and used for research and analysis.

CIAI planned to incorporate this new technology into the notewriting feature of its CHARTstation products, which were electronic medical records for different medical specialties. The company would first incorporate MEDencode into its CHARTstation gastrointestinal (GI) endoscopy product, then it would develop MEDencode knowledge bases in other medical areas.

For a clinician who still wrote patient notes, using the new technology would minimize the effort required to collect relevant patient data. The technology would also be faster than traditional notewriting and data collection. It would also enable a clinician to access a completed patient record and search for and retrieve patient data more quickly than through traditional free-text notes. Moreover, CIAI estimated that a clinician using the new technology could reduce the time spent producing patient documentation by 38 percent. This valuable savings in time could potentially enable the clinician to see an additional patient each day, resulting in a 5-percent increase in that clinician's productivity.

Many medical records lacked the detail necessary to make a valid comparison of clinicians and the care they provided.

A clinician could also reduce administrative costs by avoiding transcription fees and the need to hire certified staff to code patient information for billing. Furthermore, these clinicians would benefit from reduced costs for chart retrieval, filing, and copying after they converted to the automated system. If the new technology were widely adopted, CIAI estimated the total annual savings could reach $2 billion.

CIAI Anticipates Greater Visibility of Patient Care

CIAI anticipated that the new automated coding system would result in a medical knowledge base from which extensive clinical data sets could be obtained. These data sets would be useful to companies that were developing provider-profiling products that are used to compare the activities of one or more healthcare providers and outcome measurement tools that demonstrate the efficacy of individual healthcare providers. The availability of inexpensive high-quality clinical data would allow these companies to remain focused on designing and developing data analysis tools, rather than on performing medical research. These developmental changes would benefit the provider and payer organizations that purchased and used the new data repositories and analysis tools.

Ultimately, however, the availability of detailed patient data through the MEDencode knowledge base would

result in greater visibility of patient care by both provider and payer organizations. It was theorized that this increased clarity would result in a deeper understanding of the components of high-quality, cost-effective healthcare delivery, which would lead to more standardized provisioning of patient treatment and care.

Development of MEDencode Technology Poses High Risk

CIAI understood that automating the collection and storage of clinical data as a byproduct of clinical notewriting was a high-risk endeavor. One major risk would be designing a medical repository without a standard data model. The company would address this, however, by conducting a well-structured trial of a codified repository for GI endoscopy, a domain that was well understood. A second major risk would be developing a system that could accurately correlate the nonstandard, narrative text entered by the clinician with standardized, codified clinical data.

Because the project risks were more than CIAI could assume, the company sought financial support. After applying to other programs, the company submitted a proposal to ATP and was awarded cost-shared funding in 1994 for a three-year project under ATP's focused program, "Information Infrastructure for Healthcare."

CIAI Successfully Develops MEDencode Technology

To achieve its goal of developing technology that would minimize the effort required to collect accurate and complete patient data during the clinical process and, as a byproduct, store the collected data in a knowledge base, CIAI would have to meet five technical objectives. These objectives and CIAI's results are summarized below:

- **Objective 1:** *Design and develop a healthcare data model (MEDdb) for the codified repository of a CPR and an intermediate codified representation using an object-attribute-value scheme for codification, with appropriate dictionary support.*
  Results: Met Objective—By the end of the ATP-funded project, CIAI had successfully developed a MEDencoded GI endoscopy knowledge base. This

knowledge base was integrated into Endo Works, a product that supported GI endoscopy. Endo Works was manufactured by Olympus of America, the largest endoscopic manufacturer in the world.

- **Objective 2:** *Design and develop a knowledge base storage system for clinical objects that supports data collection, text generation, and posting of codified data to the repository.*
  Results: Met Objective—CIAI successfully developed a knowledge base storage system. In the process, the company made the decision to create separate value entries for each symptom, such as "weight loss" or "dysphagia" rather than "weight loss and dysphagia," so that a user could perform separate electronic searches for each term.

- **Objective 3:** *Design and develop domain analysis and knowledge base authoring tools for developing specialty-specific knowledge bases.*
  Results: Met Objective—By the end of the project, CIAI had developed tools that enable users to customize knowledge bases.

- **Objective 4:** *Design and develop a structured clinical note representation that can record the interaction with the knowledge base during the production of a note.*
  Results: Did Not Meet Objective—CIAI was unable to meet this objective with its current architecture. The company could not enhance the graphical user interface so that sections of a note could be independently recognized and manipulated. For example, neither the user nor the CIAI knowledge engineer could alter formatting in the text, such as fonts, indents, or bullets. However, the company planned to continue to work on this functionality and incorporate it in the next release of the software.

- **Objective 5:** *Design and develop a provider documentation engine that allows users to interact with the knowledge base in order to produce both a clinical note and codified data.*
  Results: Met Objective—Although CIAI originally planned to incorporate the new MEDencode technology into its existing CHARTstation

product line, it was unable to do so because the new technology had to be database independent. The company decided instead to build the notewriting engine for the MEDencode technology as a component that was separate from the rest of the CHARTstation code base. This component was called CHARTnote.

The field trial for the technology was conducted during the ATP-funded project at Brigham & Women's Hospital in Boston. During the trial, the CHARTnote engine successfully demonstrated that it could create narrative notes while simultaneously capturing clinical data.

CIAI Plans Several Applications of MEDencode Technology

During the ATP-funded project, CIAI began to make plans to incorporate the MEDencode technology into existing CIAI technologies. The company intended to integrate the technology into four of its existing CHARTstation reporting products: (1) GIstation for gastrointestinal endoscopy, (2) EMstation for emergency medicine, (3) EYEstation for ophthalmology office practice, and (4) RADstation for diagnostic radiology. At the same time, the company hoped to introduce a new product, FPstation, which is an electronic medical record management tool for family-practice medicine.

MEDencode would automatically gather, codify, and record specific, detailed information about a patient.

In the second year of the project, CIAI aimed to develop knowledge bases and reporting tools for additional specialty areas, such as internal medicine, pediatrics, and cardiology. Also, the company planned to develop a MEDencode toolkit and license it to development partners who could then build MEDencode-based products in other domains. CIAI would also provide training and support services to assist its partners in developing MEDencode-enabled products for their areas of the healthcare marketplace. CIAI planned to utilize a development and distribution strategy in which products for CIAI and the partners would be developed with the MEDencode technology and then distributed by market segment.

CIAI formed its first partnership during the ATP-funded project with Shared Medical Systems (SMS), a large company that at the time dominated the hospital information systems market. SMS offered to work with CIAI on codifying patient medical information (which corresponds to Technical Objective #5). Once the MEDencode technology was developed, SMS would integrate its enterprise-wide communications and repository capabilities with the MEDencode notewriting and data collection capability. The new technology would be placed in the front-end of SMS's workstations across all of its product lines. SMS would also provide CIAI with a distribution channel into the two major areas of physician clinical practice: hospital information systems and ambulatory care/group practice.

During the ATP-funded project, CIAI also began discussions with Olympus Corporation, the largest provider of fiber optic and video endoscopes in the world. CIAI met with Olympus to determine whether Olympus would distribute a MEDencode-enabled GIstation product to its established base of more than 2,000 endoscopy practices.

MEDencode Technology Is Commercialized

By the end of the project in December 1997, CIAI had successfully created CHARTnote as a separate software component for GI endoscopy and was licensing it to four key customers:

- Shared Medical Systems for its Novius product

- Olympus of America for its Endo Works product

- The Mayo Clinic

- The Central Region of the Veterans Administration (VA)

CIAI was also providing the software component to third parties who were interested in building their own CPR. By February 1998, Olympus's product Endo Works, which supported GI endoscopy, was commercialized with the new technology. Within the next few months, CIAI also added the MEDencode technology to its ophthalmology and oncology knowledge bases. At the same time, the company was collaborating with Health Technology Associates to use the MEDencode technology to create a powerful tool that would help firms monitor patient care and costs.

By 1999, CIAI had sold approximately 350 licenses for the new software. Its success also attracted another company, InfoCure, a corporation that provides information management technology and services to dentists, orthodontists, and oral and maxillofacial surgeons. In November 1999, InfoCure acquired CIAI's parent DataMedic for $25.4 million in stock.

Thousands of clinicians were using the new software to write clinical notes by May 2000. Approximately 5,000 physicians were using the technology at more than 250 endoscopy sites and 100 primary care and emergency medicine sites. The number of products that contained the module also continued to increase.

By 2000, InfoCure had also developed additional knowledge bases and had seven CHARTstation products that incorporated the MEDencode technology on the market in the following areas:

- GI medicine
- Emergency medicine
- Internal medicine and family practice
- Outpatient ophthalmology
- Renal dialysis
- Rehabilitative medicine
- Oncology

In addition, Olympus's Endo Works product was being used at several hundred hospitals and ambulatory care centers. Sales of the product were increasing by 25 to 50 percent a year.

By 2001, with year-ending revenue of $107 million, InfoCure had earned $4 million in revenue from products incorporating the MEDencode technology. In 2004, the division of the company responsible for this technology was sold to Cerner Corporation.

ATP-Funded Project Results in Additional Public Benefits

Other potential large users of CIAI's technology were anticipating significant cost savings. The VA had selected the MEDencode technology for testing because it could be integrated into other software applications, was structured so that it could generate feasible billing codes, and could support several

medical specialties. The VA anticipated that if it used the new technology, it could save up to several million dollars per year in each region in transcription fees and salaries for certified staff who perform billing coding.

In 2004, Brigham and Young Hospital received a large grant from the National Institutes of Health to perform research on patients diagnosed with colonic polyps based on data gathered through GIstation. The data collected through MEDencode-enabled technology have also been described in several professional papers.

Conclusion

With ATP's assistance, Clinical Information Advantages, Inc. (CIAI) developed a knowledge base driven automated coding system, which is a software component that makes it easier for a clinician to complete a computerized patient record (CPR). Through a series of knowledge base driven dynamic menus, key terms such as symptoms are incorporated in the CPR as the clinician completes it, resulting in a descriptive patient report. At the same time, the coded data are stored in a specialized database, where it is available for research and analysis.

Although the company was unable to incorporate the new technology into its existing notewriting technology, as it originally planned, it was able to develop a separate software component for gastrointestinal endoscopy, which it called CHARTnote. By the end of the ATP-funded project in 1997, CIAI had licensed CHARTnote to four of its major customers. The company was also providing CHARTnote to companies interested in building their own CPR.

In 1999, DataMedic (CIAI's parent company) was acquired by InfoCure, a corporation that provides information management and technology and services to dentists, orthodontists, and oral and maxillofacial surgeons. By 2000, thousands of clinicians were using the new software. InfoCure had also commercialized seven products in its CHARTstation line (electronic medical records for different medical specialties that incorporated the MEDencode technology). In 2001, InfoCure changed its name to VitalWorks, and in 2004 the division of Vitalworks responsible for this project was sold to Cerner Corporation. Since 1994, research on the ATP-funded technology has been shared through several presentations and publications.

PROJECT HIGHLIGHTS
Cerner Corporation
(formerly DataMedic–Clinical Information Advantages, Inc.)

Project Title: Coding and Storing Patient Information with MEDencode ("MEDencode" – A Technology to Populate a Clinical Data Repository as a By-product of Producing the Clinical Note)

Project: To support improved gathering of clinical information by developing tools that facilitate the production of clinical notes and, as a byproduct, gather the codified clinical data and store it in a database system.

Duration: 12/15/1994-12/14/1997
ATP Number: 94-04-0038

Funding (in thousands):

ATP Final Cost	$1,995	75%
Participant Final Cost	671	25%
Total	$2,666	

Accomplishments: With ATP funding, Cerner Corporation (formerly DataMedic–Clinical Information Advantages, Inc.) developed a software component that facilitates the production of clinical notes and, as a byproduct, gathers codified clinical data and stores it in a database system.

Commercialization Status: Since 1997, Cerner (formerly DataMedic–Clinical Information Advantages, Inc.) has successfully commercialized the ATP-funded technology. It has licensed it, provided it to companies interested in building their own computerized patient record, and packaged it with its own CHARTstation line of products (electronic medical records for different medical specialties).

By 2000, approximately 5,000 physicians were using the new software for clinical notewriting at more than 250 endoscopy sites and 100 primary care and emergency medicine sites. The number of products that incorporate the module has also continued to increase. By 2001, Cerner offered approximately seven CHARTstation products (electronic medical records) that incorporated the MEDencode technology and had earned $4 million in revenue.

Outlook: The outlook is positive for continued demand for Cerners' MEDencode-enabled CHARTnote products and licenses for the software component.

Composite Performance Score: ****

Number of Employees: 16 employees at project start, 55 as of December 1997

Focused Program: Information Infrastructure for Healthcare, 1994

Company:
Cerner Corporation
2800 Rockcreek Parkway
Kansas City, MO 64117

Contact: Mr. Darren McCormick
Phone: (816) 221-1024

Publications:

- Starkweather, R.W., and R.S. Johannes. Advanced Electronic Medical Records for Cancer Cure. Toward an Electronic Patient Record-International Symposium Proceedings, 1998, San Antonio, TX, Waegemann, C.P., ed. Medical Records Institute, 1998.

- Kahane, S.N. "Multimedia Mobile Computer-based Patient Records–Stay Close to the Patient and Have It Your Way," Toward an Electronic Patient Record-International Symposium, Vol. 2, 269, 1996.

- Rucker, D.W., R.S. Johannes, S.W. Finley, and S.N. Kahane. "Designing an emergency medicine physician workstation to support risk management in decision making," Proc. of the American Medical Informatics Association Annual Fall Symposium, 787-91, 1996.

- Kahane, S.N. "Computerized Patient Records for the Continuum of Care Critical Technology for Managing Care & Measuring Outcomes," Toward an Electronic Patient Record-International Symposium, Vol. 2, 395-96, 1995.

- Kahane, S.N. "User Interface Technology for Computerized Patient Records Have it Your Way – Speech Recognition, Pen-Tablet and Voice Recording," Toward an Electronic Patient Record-International Symposium, Vol. 2, 343-51, 1995.

- Rucker, D.W., R.S. Johannes, S.W. Finley, and S.N. Kahane. "Aspects of Risk Management Support for an Emergency-Medicine Physician Workstation," Journal of the American Medical Informatics Association, 976, 1994.

PROJECT HIGHLIGHTS
Cerner Corporation
(formerly DataMedic–Clinical Information Advantages, Inc.)

Presentations:

- Johannes, R. "From MEDencode to MEDassist," ATP National Meeting, November 1999.

- Kahane, S.N. "Multimedia Mobile Computer-based Patient Records – Stay Close to the Patient and Have It Your Way," Toward an Electronic Patient Record-International Symposium, San Diego, CA, May 1996.

- Rucker, D.W., R.S. Johannes, S.W. Finley, and S.N. Kahane. "Designing an emergency medicine physician workstation to support risk management in decision making," American Medical Informatics Association Annual Fall Symposium, Washington, D.C., October 1996.

- Kahane, S.N. "Computerized Patient Records for the Continuum of Care Critical Technology for Managing Care & Measuring Outcomes," Toward an Electronic Patient Record-International Symposium; Orlando, FL, March 1995.

- Kahane, S.N. "User Interface Technology for Computerized Patient Records Have it Your Way – Speech Recognition, Pen-Tablet and Voice Recording," Toward an Electronic Patient Record-International Symposium; Orlando, FL, March 1995.

Research and data for Status Report 94-04-0038 were collected during May – August 2004.

Cerner Corporation   63

InStream Corporation

Development of Seamless Electronic Data Processing for the Behavioral Health Care Sector

In the early 1990s, the transaction-processing systems used by the medical services sector were paper-based, cumbersome, and slow. Behavioral healthcare (BHC) providers, who deal with problems such as alcoholism, depression, and traumatic stress, exchanged paper referrals, authorizations, evaluations, and claims via the U.S. mail with multiple managed care payers. To address this problem, a joint venture sought to use the emerging electronic commerce environment, or World Wide Web, to facilitate this data processing.

InStream Corporation, a company founded to develop an automated transaction processing product for the electronic commerce market, formed a joint venture with two other companies to apply for Advanced Technology Program (ATP) funding under the focused program, "Information Infrastructure for Healthcare."[1] The partnership proposed to improve the entire transaction flow for the BHC sector by developing software that providers could install on their office computers. This software would analyze each transaction for accuracy and completeness as stipulated by the receiving payer. After the providers corrected any errors or omissions, one mouse click would "instream" a batch of claims to the payer(s) through AT&T's EasyLink Electronic Data Interchange (EDI). This process would be faster and more accurate and would involve less human intervention, which would reduce the cost of BHC transaction processing. Eventually, although a variety of transactions was fully supported by the InStream software, the primary interest for providers was in having claims paid quickly. Therefore, InStream devised a multiplayer transaction service called "MultiClaim" to meet that need by using the InStream software.

MultiClaim software was never fully successful because payers developed their own Web portals or interactive real-time transaction Web sites that they felt kept their proprietary interests at lower costs. Consequently, the major providers and their payers had no need to seek a custom product such as MultiClaim.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

No Stars

Research and data for Status Report 94-04-0018 were collected during March – May 2004.

Behavioral Healthcare Claims Processing Was Fragmented

In 1994, less than 5 percent of the $100 billion in claims from the mental health and substance abuse services sector was processed via computer. Claims verification and processing was cumbersome and time consuming because providers had to submit and receive to and from several payers a chain of transactions (referrals, authorizations, evaluation reports, follow-up reports, and claims) all on paper, most often via U.S. mail. A joint venture consisting of InStream Corporation (claims initiator and processor), Axint Corporation (a software developer), and AT&T EasyLink, one of the first electronic data interchange (EDI) networks, wanted to solve the problem by automating forms generation as much as possible. They proposed to design a system that would automatically generate and fill in the information on an electronic medical claims transaction form, without the additional cost of human intervention.

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[1] The project was changed to single applicant status two years after project start.

Whatever forms were needed would be automatically generated when certain transaction types were selected. Moreover, most of the data would be filled in electronically on the forms from other forms for a given patient, forms that had already been received in the behavioral healthcare (BHC) providers' offices. This automated process would link forms together and send them electronically, after fulfilling edits and validations, thus saving time and money compared to the paper chase of send, receive, correct, and send again.

The fragmented nature of the BHC sector made it particularly suitable for automation. At the time of the project proposal, there were more than 320,000 individual BHC providers and provider organizations in the United States, including hospitals, clinics, psychiatrists, psychologists, social workers, counselors, and therapists. Due to the complexity of the transactions and the multiple payer and provider management systems in place, private funding to finance this kind of high-risk research to automate the transaction process was difficult to obtain. However, the joint venture partners felt that a successful prototype would speed acceptance of electronic processing. For example, the partners estimated that if prototype software were successful and widely accepted, this software could save $9 billion annually in the BHC sector alone. A successful solution would also enhance the quality of patient care by simplifying hospital admissions and medical treatment claims processing. Furthermore, a successful prototype would attract more private venture capital. (After InStream successfully developed and tested the prototype, the company received $8.3 million from several venture capital firms.) Based on these significant anticipated benefits, the joint venture submitted a proposal and won ATP funding in 1994 as part of the "Information Infrastructure for Healthcare" focused program. The two-year project began in 1995.

Entrepreneurial Companies Faced Challenges in the Behavioral Healthcare (BHC) Market

The challenges the joint venture faced in developing an electronic transaction-processing system were daunting. Several reasons for this are described below:

- Resistance to innovation by the largest managed care organizations (MCOs). Under the managed care system, the MCO's created networks of physicians, hospitals, and other healthcare professionals in order to manage cost, quality, and patient access to healthcare. The MCOs were reluctant to pay for and implement a system that would require them to enforce standardized transactions with their network providers. Since the providers belonged to multiple MCO networks, the fear was that their competitors would simply take advantage of the InStream claims-transaction technology that they would have paid to install and train providers to use. The MCOs viewed that possibility as a loss of competitive advantage. However, the implementation of the Health Insurance Portability and Accountability Act (HIPAA) of 1996 addressed that problem by 1998 by enforcing the eight primary, standardized EDI transaction data sets. This enforcement removed any competitive advantage previously gained by using the proprietary (processing) data sets used by MCOs.

- Computer system incompatibilities. MCOs and their provider groups had widely varying and incompatible levels of computer hardware and software functionality. For example, an MCO might have a UNIX platform, while a provider's office might use a DOS or Microsoft Windows platform.

- The highly sensitive, subjective, and non-standardized nature of behavioral health records. The BHC sector has historically been resistant to automating records, partly due to privacy issues. Behavioral health issues involve social problems like alcoholism or drug abuse, so maintaining strict client confidentiality regarding patient records is necessary. If patients feared that their confidentiality might be breached, they might not seek needed treatment. This increased providers' reluctance to use an unfamiliar electronic system that did not have a physical presence like paper records or even facsimile copies.

"One-Click" Solution Could Streamline Transaction Processing

InStream's plan was to create a software product that was easy to install and use and that could interoperate with other records-processing programs on a commonly used platform, such as Microsoft Windows. InStream's original intent was to provide full BHC managed care document cycles beginning with the referral, which is the first step leading to services that would generate a claim. This function would be performed by the

InStream Provider Network (IPN) software (the version IPN3.0 was the first release; toward the end of the project 3.1 was released, as depicted in Figure 1). However, early in the project, the team realized that the providers' immediate need was for the claims completion process, or paying the providers for their services. In response to that need, InStream developed the MultiClaim service, based on their IPN software, for installation on the providers' office personal computers (PCs). The joint venture developed a Windows version first, then the intention was to follow with other PC operating systems software.

Figure 1. The IPN software, shown in its last release 3.1, provided full behavioral managed care document cycles.

MultiClaim was a business process service that used an application programming interface between the IPN software and the provider's practice management system. MultiClaim provided a one-to-one and a one-to-many method for the claims-filing process. ("One-to-one" is when the provider transacts directly with one payer; "one-to-many" is when one provider sends multiple types of transactions to several payers for different services for different patients.) The MultiClaim service and software would process all the required forms to accomplish the tasks necessary to complete the filing. The software was installed on the provider's PC, enabling the provider to submit a batch of claims for several clients. The software would then open each claim and analyze it for errors and completeness. After the provider corrected any identified omissions or errors, the provider then submitted the batch electronically (via AT&T's EasyLink) to InStream. InStream sent the individual transactions either directly to the payer or through the payer's clearinghouse. (A clearinghouse is a service that contracts with multiple payers to perform some of the claims processing that InStream aimed to provide. One of InStream's business goals for MultiClaim was to have the software replace

the function of the clearinghouse as more payers signed up for direct transactions.)

Initial Product Development Progress

The joint venture partners planned to spend the two years of ATP funding on research, development, and testing. After that, the funding would be self-sustaining as paying clients were serviced by the MultiClaim product. The software to be developed by InStream involved modifying Axint's exiting product called FormLink. This proprietary form-generating software was originally designed for property and casualty insurance clients to facilitate automation and reduce paper transactions between the companies and their independent agents.

The first obstacle in modifying FormLink for the ATP-funded project surfaced several months into the first year. When InStream began talking to MCO clients who could pilot-test the software to be developed, InStream's sales team noticed reluctance among the payer users to participate in the pilot test. Axint felt that customization to meet the MCO requests would make FormLink too unique for its own commercial-off-the-shelf product plan. Consequently, InStream changed its relationship with Axint from partner to subcontractor in mid-1996 in order to enhance the product's future marketing prospects by taking over the customization of code and not relying on the FormLink software. By changing the nature of its business partnership with Axint, InStream reduced the visibility of its relationship with Axint, since MCOs were concerned about the dependency of the relationship. (In the BHC claims transaction business, excessive dependence on customized software was not regarded as a solid foundation for future business growth). With Axint as a subcontractor, InStream successfully completed pilot tests of the software by October 1996 with five MCOs, among them U.S. Behavioral Health, Foundation Health MHN, and Magellan.

InStream Faces Marketing Challenges During the Commercialization Year

After the conclusion of the research and development phase of the project in April 1997, at the same date that the ATP project ended, InStream was working with 24 provider practice management vendors. (A practice management vendor sells products to help doctors with

the day-to-day management of their practices, such as patient billing). These 24 vendors serviced 75 percent of the BHC provider market. Approximately 72 provider provider facilities, or 1,500 practitioners, had signed up and were using the software and services with four MCOs, which represented 45 percent of the BHC market. (In 1996, nine MCOs had 85 percent of the market. An MCO's provider base ranged from several groups to over a thousand groups. The average number of providers in a group was three.) However, at the conclusion of the research and development phase, InStream management realized that they had not developed an effective sales program to target the MCOs. They then began work on implementing a sales plan, and after a few months, sales increased. However, the company began to falter later when several MCOs did not follow through on their commitments to buy and roll out the product to their provider networks. About this same time, AT&T lost interest in providing the EDI platform for transmitting the claims, after the InStream management team decided to enable MultiClaim to work on the Web, not requiring the use of AT&T's EasyLink EDI.

The prototype software could save $9 billion annually in the BHC sector alone.

In March 1998, subcontractor Axint was falling behind in providing technical support for the continued software modifications required by InStream. This support backlog caused a delay in bringing accomplished sales of the software online. (Only about 10 percent of the sales at that time had been brought successfully online.) That same month, a year after the project ended, InStream's product marked its first operational and sales success from a telemarketing effort. One thousand provider facilities had bought the software, which translated to 1,000 to 10,000 practitioners (depending on how many practitioners resulted from each facility). Many of the providers had been sending claims through a clearinghouse, which validated them and then forwarded the claims to the payers. Envoy, a prominent clearinghouse used by many MCOs, agreed to become the partner clearinghouse with InStream because of the overwhelming number of payers already using Envoy. Envoy and Instream agreed on what claim data formats coming out of InStream's software were acceptable and correct for Envoy to forward to the payer. InStream continued to provide the end-to-end

transaction services for the clinical forms that Envoy did not support such as referrals, authorizations, evaluations, and follow-ups.

InStream Attempts to Navigate the Entrepreneurial Hazards of the Dot-Com Period

Although InStream made progress in signing up clients and shipping MultiClaim after the ATP-funded project ended, the company's commercialization efforts ended because of two major obstacles in the BHC market.

First, the MCOs were suspicious of independent small companies using proprietary software, viewing these companies as competition. The MCOs did not want the small companies to become electronically enabled. Early in the post-project commercialization stage, InStream had only 60 BHC facilities fully online of the 1,000 that had signed up. This was because U.S. Behavioral Health had paid InStream to train only their provider members how to install and use the MultiClaim software. (Not all of the 1,000 provider signups were U.S. Behavioral Health's). Sixty facilities out of 120 U.S. Behavioral Health preferred provider sites were fully functional since there was an incentive to use a service they were paying for. The remaining providers, which were not being paid by any MCO to participate, had no incentive to use the software right away. The 60 paying facilities represented about 1,000 practitioners, numbers that seemed too small to the other MCOs. In late 1998, a new chief information officer at one of the larger MCOs changed that company's priorities and subsequently the MCO cancelled its commitment to implement MultiClaim throughout one of the New England states. U.S. Behavioral Health, who had been an early adopter and supporter, delayed its own plans for a national rollout into its next fiscal year. About this same time, yet another smaller MCO also cancelled its commitment with InStream for unspecified reasons. In general, the MCOs were nervous about the merger climate that was evolving at that time, and they did not want to make expenditures they would have to cancel later.

The second obstacle was that the Health Care Financing Administration (the agency that administers Medicare) began to grant exemptions to states to "carve out" portions of the Medicaid BHC sector for privatization. (Privatization is the changing of payer

reimbursement from Medicaid to any company competing with the MCOs to provide the same services.) This meant that the BHC MCOs needed to spend more on fighting marketshare battles than on a new technology for provider transactions. With all the mergers going on, the MCOs did not want to lose any market share to competing companies.

By October 1998, MultiClaim had been commercialized and sold to more than 1,200 facilities, and 600 were actively using the software. However, InStream needed more cash to continue to provide upgrades to the software and to expand into other healthcare segments (such as home healthcare and workers' compensation). An investment banker worked with InStream and the original venture capital investors to make five acquisitions to improve both market share and cash flow. Subsequently, this final round of financing (called "mezzanine" in the venture capital business) before the Initial Public Offering collapsed when the investment banker withdrew financing due to negative market conditions for all healthcare technology ventures. An influencing factor was the postponement by two MCO InStream clients that had previously indicated they were going to sign on with the InStream software. In addition, a third MCO client cancelled altogether. Unable to secure more funding, InStream went out of business in October 1998.

Aftermath: Lessons Learned

The InStream management team acknowledged several factors that impeded the commercialization of the InStream Provider Network software and the MultiClaim services based on it. Chief among them were the following:

- Ignoring the challenge of legacy (incumbent) systems already in place at MCOs that were often outdated.The large MCOs were wary of products that did not easily interface with their in-house systems.

- Rapid consolidation of the BHC MCO market during the course of the project. InStream found that, in the event of a merger or takeover, orders for new technology products or services, such as InStream's products, were usually canceled.

- Pursuing an unsolicited, entrepreneurial solution rather than a solution in response to a Request for Proposal or similar solicitation from the industry. The BHC transaction processing market seemed ready for a software product like IPN and MultiClaim. However, competitors were pursuing the same idea and the same venture dollars. A successful mezzanine financing would have provided capital to continue commercialization efforts, but the mezzanine financing did not occur as planned and the failure of the product was inevitable.

- Building a complicated system with too little MCO buy-in to service customers.This became an intense capital drain for InStream during a time when competitors and the MCOs themselves were catching up to the technology and building their own Web-enabled portals.

Despite the failure of the product, it is notable that InStream created the first BHC Web portal. In the pioneering days of electronic commerce, a Web portal for the BHC sector was a new concept. It provided transaction services (MultiClaim), daily news about the industry, continuing on-line education, and a bookstore. Any BHC provider with Web access could join and use these services through their Web browser.

By October 1998, MultiClaim had been commercialized and sold to more than 1,200 facilities, and 600 were actively using the software.

InStream published one book chapter and articles in two journals on the ATP-funded technology. They presented at 11 conferences and received press coverage in 22 publications. As of 2004, products like MultiClaim and its competitors were obsolete due to the development of extensible mark-up language (XML), a Web-engine language that is independent of operating systems such as Microsoft Windows (with which MultiClaim was designed to interoperate). Axint and InStream went out of business after the conclusion of the project. AT&T EasyLink was acquired by Swift Telecommunications in March 2001.

Conclusion

InStream, AT&T EasyLink, and Axint created a joint venture to streamline the electronic submission of behavioral healthcare (BHC) transactions. The joint venture developed a software product, InStream Provider Network (IPN), and a service based on it, called MultiClaim, that could be installed on providers' personal computers to examine and prepare batches of BHC claims and clinical transactions for submission to payers. MultiClaim saved time and money and helped to improve the claims-submittal process. At its most successful sales point in the post-project period, InStream sold its product to more than 1,200 provider facilities. However, the company was unable to obtain additional venture capital to continue the necessary upgrades and market penetration for their product. Subsequently, the company went out of business approximately one and a half years after the ATP-funded project concluded. Although IPN and MultiClaim were never successfully commercialized, the partners pioneered the first electronic commerce BHC Web portal, which was quickly copied by competitors such as WebMD Envoy in the late 1990s. (WebMD Envoy is a conglomerate of several payer clearinghouses that was acquired by WebMD.) MultiClaim served as the precursor to similar software now in use by many managed care organizations (such as Athenahealth and Navimedix). This type of software has replaced some use of clearinghouses, because it performs many additional functions not previously performed, such as customer eligibility verification. InStream also published its findings in a significant number of publications before the company went out of business.

PROJECT HIGHLIGHTS
InStream Corporation

Project Title: Development of Seamless Electronic Data Processing for the Behavioral Healthcare Sector

Project: To develop a flexible electronic forms system for the behavioral health segment of the healthcare industry and to integrate the system into an easy-to-use, low-cost, accessible electronic network.

Duration: 5/1/95-4/30/97
ATP Number: 94-04-0018

Funding (in thousands):

ATP Final Cost	$1,370	50%
Participant Final Cost	1,382	50%
Total	$2,752	

Accomplishments: With ATP funding, InStream led a joint venture to create the first behavioral healthcare (BHC) Web portal for claims processing.[1] During the project, InStream piloted the system with U.S. Behavioral Health, Foundation Health MHN, and Magellan. Similar portals are in use today by the five largest managed care organizations (MCOs).

Commercialization Status: The software product was briefly commercialized in 1998, but was quickly overtaken by competing products after a lack of funding prevented InStream from providing the necessary upgrades and market penetration to reach positive cash flow. Subsequently, InStream went out of business.

Outlook: The outlook for this software is weak because competitors developed similar software and overtook InStream's product before the company could maintain its lead position by rapidly introducing software updates. Moreover, the company was not able to obtain the venture capital needed to sustain its product to dominance in this market. Today, BHC portals use extensible markup language (XML), a nonproprietary screen text-processing capability that greatly reduces the costs of data transfer. The use of XML was foreseen by the InStream management team toward the end of this project, before it was developed by competitors.

Composite Performance Score: No Stars

Number of Employees: 15 at project start, 0 as of April 2004

Focused Program: Information Infrastructure for Healthcare, 1994

Joint Venture Companies:

The following two companies went out of business:
Lead Company: InStream Corporation
Partner: Axint Corporation

Contact: Dr. Michael W. Hurst (formerly at InStream, now at DeNovis, Inc.)
Phone: (781) 372-3865

AT&T EasyLink (acquired by Swift Telecommunications)
200 Park Ave., 38th Floor
New York, NY, 10166

Contact: Swift Telecommunications
Phone: (212) 445-1800

Subcontractors:
Axint Technologies Corporation (joint partner from May 1, 1995 to May 9, 1996; subcontractor thereafter. (Company is out of business)

Publications:

The project team published the following book chapters:

- Hurst, M. and W. Roiter. "Electronic Data Interchange: A Revolution in How Professionals Communicate." In Trabin, T. (Ed.), *Behavioral Informatics Tomorrow: How Computerization is Transforming Healthcare*. San Francisco: Jossey-Bass Book Publishers and CentraLink, 1996.

- Hurst, M.W. and W. A. Roiter. "The rapid growth of electronic communication." In Trabin, T. (Ed) *The Computerization of Behavioral Healthcare*. San Francisco, Jossey-Bass Publishers, 1996.

The project team published the following articles in journals:

- Roiter, William. "*Soft* Information vs. *Hard* Data," *Employee Assistance*. 1995: August/September.

- Hurst, M. "Going Electronic." *Behavioral Healthcare Tomorrow*. 1995: September/October.

- Rosen, Larry, Ph.D. "The Dawning of the Electronic Commerce Age," *The National Psychologist*, 1996: September/October.

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[1] The project was changed to single applicant status two years after project start.

PROJECT HIGHLIGHTS
InStream Corporation

The project received press coverage in 17 news publications:

- "InStream is just what the doctor ordered", Massachusetts High Technology, December 30, 1996.

- Hurst, M.W., C. Muzilla, and S. Graves. "What Role Does Electronic Commerce Play for Behavioral Healthcare?" *Infoconsult News*, 1997: 1(6), 1-2.

- "The First Accredited Online Behavioral Health Courses Will Be Provided, " *Psychotherapy Finances,* April 1997.

- "Rx for Health Care Info", *PC Week*, May 5, 1997.

- "Electronic Commerce Solution Speeds Reimbursements", *Information Management Week*, May 7, 1997.

- "Electronic Commerce Cuts California Group's Time Spent on Paperwork in Half," *Managed Behavioral Health News*, May 15, 1997.

- "InStream Unveils Electronic Commerce for Claims; Providers See Quicker Turnaround," *Managed Behavioral Health News*, May 15, 1997.

- "InStream Releases New Offering," *Massachusetts High Technology*, May 19, 1997.

- "InStream Corporation," *Open Minds*, June 1997.

- "Managed Care Info Exchange," *Insurance and Technology*, June 1997.

- "InStream Corporation and CMHC Systems, Inc.," *Managed Behavioral Health News*, June 12, 1997.

- "InStream Partners with 11 Vendors," *Information Management Week,* June 18, 1997.

- "InStream Teams Up With CMHC Systems," *Mental Health Weekly*, June 30, 1997.

- "HMO-PCP Information Flows InStream," *Medical Interface*, July 1997.

- "Changing the Face of Healthcare," *Electronic Commerce World*, July 1997.

- "InStream Announces Partnership with Creative Socio-Medics," *Information Management Week*, July 16, 1997.

- "InStream and Creative Social-Medics Will Integrate," Managed Behavioral Health News. July 17, 1997.

The project produced 11 presentations, of which the following are a sample:

- Hurst, M. (Moderator) "Electronic Communications between Providers and MCOs -- A Good Thing?" Behavioral Informatics Tomorrow Conference, New Orleans, LA, March 9, 1996.

- Hurst, M. and Fain, E. (Co-Moderators) "Software Development for Behavioral Healthcare." Behavioral Informatics Tomorrow Conference, New Orleans, LA, March 9, 1996.

- Roiter, W. "Toward an Electronic Patient Record: Networking Providers and MCOs." Medical Records Institute Conference, San Diego, CA, May 15, 1996.

- Hurst, M.W. 1997. "How to Use Emerging Communication Technologies to Streamline and Improve Care Management and Delivery." Fourth Annual Behavioral Informatics Tomorrow Conference, Tampa, FL, March 7, 1997.

- Hurst, M.W. 1998. "Electronic Commerce Model Applied to Managed Healthcare: Provider Adoption Challenges." Fifth Annual Behavioral Informatics Tomorrow Conference, San Antonio, TX, March 6, 1998.

Lucent Technologies (formerly AT&T Bell Laboratories)

Reusable Software for Computing Networks

In the mid-1990s, a new type of business telephone network was evolving: the computing network. A computing network was an integration of software and "intelligent devices" that used their own software. Thus, on one network, a user could process voice, faxes, and video; moreover, the network also had speech recognition capability. This idea interested product line managers at telecommunications companies, and they began to design new software products for the versatile computing network.

Through its Bell Laboratories research arm, AT&T, a leader in telephone service and research, wanted to design a software tool that nonprogrammers could use to build their own computing networks to handle incoming voice, fax, and other data traffic. After a successful implementation in the small and home office environment, AT&T predicted that the software could be scaled to larger businesses. This technology was risky due to variables that had to work together seamlessly in order to operate successfully. AT&T wanted to mitigate the technical risk for research in the highly competitive, deregulated telecommunications industry, so the company applied for Advanced Technology Program (ATP) funding and received an award under the 1994 "Component-Based Software" focused program.

Their product, called Symphony, successfully demonstrated the basic functions required for a do-it-yourself network. Then, while development was still underway, AT&T spun off the technology to Lucent Technologies, which continued the research. In July 1997, several months before the ATP-funded project ended, Lucent acquired Octel Communications, which had already developed a product that accomplished the same tasks as Symphony. Lucent discontinued work on Symphony in favor of promoting the Octel product line, which it later spun off to Avaya. Avaya still sells Octel products, which do not appear to incorporate the Symphony technology.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)

No Stars

Research and data for Status Report 94-06-0011 were collected during July – August 2004.

Business Telecommunications Evolve from Voice Only

In the 1990s, the business telecommunications industry was facing a new challenge in its evolution: the emergence of computing networks. A computing network is a group of phone lines and other devices, such as fax machines and personal computers (PCs), that are interconnected on a network. Complex software, both on the network and in the individual devices, drives each step of the phone voice or data message transmissions. Telecommunications companies such as AT&T, a major provider of local and long-distance telephone service, wanted to win market share in the emerging computing networks arena. Many companies were vying for a share of the computing network market, and the competition to enter this new market was stiff. The software necessary to oversee and manage a computing network was enormously complicated and expensive to develop. At that time, AT&T was feeling its way through the computing network's new business opportunities created by a Federal consent decree that resulted in the deregulation of the telephone business. This decree opened to

competition services that formerly had been solely AT&T's. In this highly competitive climate, AT&T applied for and received ATP funding for a two-year project under the 1994 "Component-Based Software" focused program. AT&T proposed to develop a software system to enable a nonprogrammer to build and customize a reliable computing network to manage business phone calls. The first market for this software would be the small office/home office environment. Later, AT&T hoped to enhance the software so that it could handle the network computing needs of larger businesses.

AT&T Considered Computing Network Complexities

Designing software to process calls on a computing network was challenging; the more services offered on a call, or on the network transporting the call, the more complicated the software and its updates must be. For example, if a network offers voice command capability, that feature adds a layer of complexity because the voice recognition software component must properly recognize the commands. In the mid-1990s, these capabilities were not available to small businesses, because of the complexity of developing custom applications for each business. The more complicated the network software becomes, the more functions need to be simultaneously monitored by the software's highest level function in order to prevent or fix call processing that can go awry in the transmission process. The software must have a high degree of fault-tolerance, which is the ability for the software to guess, if necessary, which step to take after the previous step is completed. This might be necessary due to conflicts resulting when many devices, each with its own unique software, are interconnected on a network.

Tool Needed to Build a Customized Computing Network

AT&T wanted to design reusable software that a nonprogrammer could use to build a customized, fault-tolerant computing network for small businesses. If successful, this software would reduce the high cost of updating and maintaining the call-processing software. The foundation of the software would be "building blocks" that the user would employ to assemble a customized computing network that consisted of only

the functions the user needed. An example of one of these building blocks is an announcement that would play when the called party was not available. This was and still is a common component in a typical phone-messaging system. The building blocks would reside in a library that the user could access through a PC graphical user interface (GUI) in order to build the customized network. Because the reusable software library had hundreds of building blocks, networks ranging from simple to complex could be built. AT&T named its proposed software "Symphony," after the idea that all the pieces of the software would work together to perform a function, just as the musical instruments in an orchestra play together to perform one composition.

Symphony Would Deliver New Call-Handling Features

Ideally, AT&T wanted to design the Symphony software architecture with call-handling features that could be achieved without frequent software or hardware upgrades. The following were the desired call-handling features:

- Programmability, which is the ability to modify or update functions

- Reliability, including fault tolerance, which is a necessary characteristic of any computing network

- Interoperability, which is the capacity to interface with other software and hardware

- Scalability, which is the ability to easily increase line or message capacity

- Low cost, which would make the software affordable for small businesses and home offices

Building a system with these features was daunting, because complex software-governed networks were inherently prone to unpredictable bugs, because of the frequent updates required to accommodate new functionality and new technology. The greater the complexity of the software, the greater the potential for bugs. In the mid-1990s, computing networks were not

capable of delivering the five features that AT&T identified. Nor were the traditional voice networks able to deliver this enhanced functionality; their services were limited to the basic calling services of call answer, call hold, call transfer, and conference-calling. The traditional voice networks did, however, offer a better quality of service for the basic calling services than the emerging computing networks were able to offer.

AT&T Collaborates to Test Symphony

During its development work on Symphony, AT&T teamed with the Center for Reliable and High Performance Computing, a division of the computer science department at the University of Illinois in Champaign-Urbana. Several computer science graduate students tested versions of Symphony with the university's simulation software called "Depend." Depend could simulate stresses that Symphony would encounter, such as a high number of calls or the failure of critical system components. The developers from the university and AT&T used Depend to test Symphony through many cycles of iterative modeling, analysis, prototyping, and revision. By the end of the ATP-funded project's first year, AT&T had completed the initial architecture and had performed a demonstration of a very simple computing network. The researchers also used Depend to successfully test the following technical challenges:

- Connection failure detection, or how long it would take Symphony to sense that a call has accidentally disconnected due to a software or hardware failure

- Connection recovery time, or how long it would take a system to reconnect an accidentally disconnected call due to a software or hardware failure

- Connection reconfiguration time, or how long it would take the software to find an alternative route to reconnect an accidentally disconnected call

Corporate Restructuring Causes Change of Focus

Following the first demonstration of Symphony, AT&T worked on issues related to more complex versions of Symphony. They made progress toward a stable complex build, but an AT&T corporate restructuring interrupted development. In order to enable AT&T to compete in the newly deregulated long-distance market, the Symphony development group was spun off into Lucent Technologies in 1996. After the spin-off, Symphony, in its original form, never regained its momentum, partly due to staff losses and transfers associated with the restructuring.

Lucent Attempts Viper Development

To regain Symphony's product development momentum that was hobbled by AT&T's restructuring, Lucent attempted in 1997, the last project year, to develop a simpler messaging product for the computing network environment called "Viper." Viper was based on the Symphony software design and worked under Microsoft Windows. This product was intended for an emerging market: the high-availability, low-cost, small-office systems for voice and Internet data communication. Although Viper was originally slated for delivery in the first quarter of 1998, it was canceled in late 1997 when Lucent acquired Octel Communications. Octel was a provider of voice, fax, and electronic messaging technologies and already had a phone-messaging product called Octel Messaging Systems, which had a solid customer base, and was similar to Symphony.

The software necessary to oversee and manage a computing network was enormously complicated and expensive to develop.

After acquiring Octel, Lucent made attempts to integrate Symphony, or parts of its design, into other ongoing product development efforts. For example, two Lucent clients needed speech-recognition circuitry for their business solutions, which was one of Symphony's functions. However, developers were unable to integrate this capability. Consequently, Lucent decided to discontinue developing Symphony, because most of its functions were already available in the Octel Messaging Systems. In 2000, Lucent spun off the Octel messaging product line to Avaya, which still sells Octel messaging products. It is unlikely that any of Symphony's functionality was integrated into Octel's product line.

Despite the discontinuation of Symphony, Lucent software developers gained a better understanding of modular (building-block) software architecture for dependable telecommunication services. They achieved some success with reusable software components on a Microsoft Windows platform, with minimal customization to the building-block architecture. Lucent also published 11 articles and papers resulting from company or industry forums and conferences.

Conclusion

In the mid-1990s, the computing network in the business environment was evolving rapidly, along with the capabilities, costs, services, and architecture of business telephones and personal computers (PCs). With these advancements came needs to control and enhance the capabilities of the devices on those networks. AT&T, a dominant telephone service provider, proposed to develop, through its Bell Laboratories, a technology that would reduce the costs of upgrading and maintaining computing networks. Their proposed software tool would use reusable software building blocks, which provided an easy-to-use tool for nonprogrammers.

The product, called Symphony, targeted the small office and home office environment. Although AT&T successfully demonstrated the product at the end of the first year of the project, Symphony was not developed further because of AT&T's corporate restructuring in 1996. The technology was transferred to Lucent Technologies, a company spun off during the restructuring. Shortly after this transfer, Lucent acquired Octel Communications, which already had a viable voice-messaging product. Octel products were later spun off to Avaya in 2000. Even though Symphony was never fully developed, software developers gained a greater knowledge of modular (building-block) software design and published 11 papers and professional journal articles.

PROJECT HIGHLIGHTS
Lucent Technologies (formerly AT&T Bell Laboratories)

Project Title: Reusable Software for Computing Networks

Project: To develop an easy-to-use, graphics-user interface (GUI) software assembly system that allows nonprogrammers to build reliable, custom-designed software by using libraries of reusable software components.

Duration: 2/15/1995–12/31/1997
ATP Number: 94-06-0011

Funding (in thousands):

ATP Final Cost	$1,711	46%
Participant Final Cost	1,973	54%
Total	$3,684	

Accomplishments: AT&T was able to develop and successfully demonstrate their software, Symphony. Moreover, AT&T (part of which was later acquired by Lucent) gained a better understanding of modular software architecture for dependable telecommunications services.

Commercialization Status: No commercialization resulted from this project. Lucent obtained a product similar to Symphony when it acquired Octel Communications. Consequently, Lucent decided to discontinue its development of the reusable software component product Symphony.

Outlook: The outlook for this technology is weak. Many competing companies offer similar technologies and levels of phone-messaging services.

Composite Performance Score: No Stars

Focused Program: Component-Based Software, 1994

Company:
AT&T Bell Laboratories
2000 North Naperville Road
Naperville, IL 60566

Contact: Alexander B. Dadson
Phone: (908) 582-5495

Publications:

- Levendel, Y., "The Cost Effectiveness of Telecommunications Service Dependability," *Software Fault Tolerance*, ed. Michael R. Lyu, Wiley, pp. 278-314, 1995.

- Huang, Y., and C. Kintala. "Software Fault Tolerance in the Application Layer," *Software Fault Tolerance*, ed. Michael R. Lyu, Wiley, pp. 231-248, 1995

- Levendel, Y. "Software Assembly Workbench: How to Construct Software Like Hardware," Proceedings of 1995 IEEE International Computer Performance and Dependability Symposium, Erlangen, Germany, pp. 4-12, April 24-26, 1995.

- Beyler, E., O. Clarisse, E. Clark, Y. Levendel, and R. Richardson. "An ATM-Based Platform for Rapid Generation of Multimedia Applications," *AT&T Technical Journal*, 74:5, September/October 1995, pp.106-116.

- Symphony Project Team. "Symphony: In Concert with Reuse," Lucent MultiUse Express, 4:1, February 1996 (AT&T).

- Duesing, E., Y. Huang, P. Kapauan, C. Kintala, Y. Levendel, J. Lumsden, J. Purcell, and G. Suri. "Using Distributed Resource Management in Heterogeneous Telecomputing Platforms," Proceedings of the IEEE International Computer Performance and Dependability Symposium, September 1996.

- Huang, Y. "Developing Reliable Applications on Cluster Systems," Position Paper Presented on the Industry Perspective on Reliable Distributed Systems Panel of the 15th Symposium on Reliable Distributed Systems, October 23-25, 1996, Niagara-on-the-Lake, Ontario, Canada.

- Kapauan, P., Y. Levendel, J. Lumsden, and J. Purcell. "Delivering Dependable Telecommunication Services Using Off-the-Shelf Commercial Components," Third ISSAT International Conference on Reliability and Quality in Design, March 12-14, 1997, Anaheim, CA.

- Kapauan, P., Y. Levendel, J. Purcell, Z. Kalbarczyk, T. Liu, and R. Iyer. "Modeling and Dependability Evaluation of a Heterogeneous Distributed Resource Cluster for Telecommunication Services," Lucent Technologies Reliability Information Forum - RIF97, May 1, 1997.

- Duesing, E., R. Iyer, Z. Kalbarczyck, P. Kapauan, I. Levendel, J. Lumsden, and J. Purcell. "Software Architecture for Dependable Telecommunication Services Using Commercial Off-the-Shelf Components," International Switching Symposium: World Telecommunications Congress, September 21-26, 1997, Toronto, Canada.

- Duesing, E., P. Kapauan, C. Kintala, H. Levendel, J. Purcell, and N. Southwell. "An Add-On Fault Detection and Management System for Symphony," Lucent Technologies Reliability Information Forum, April 28-May 1, 1998, Bell Laboratories, Indian Hill, IL.

SciComp, Inc.

Automatic Synthesis of Computer Code for Mathematical Modeling

To effectively analyze systems such as traffic management, electrical or mechanical implementations, weather prediction, or economic or financial models, researchers need tools to gain a better understanding of these complex systems. A very popular tool for system analysis is software modeling. Mathematical software modeling methods, which gained popularity in the mid-1990s, are widely used, especially in creating complex financial models. During that time, one of the firms championing this method was SciComp, Inc. a software development firm in Austin, TX. SciComp proposed to develop new technology that would eliminate the programming task for modelers by automatically synthesizing computer code from high-level specifications. The synthesized code would be in the form of a component, which could then be reused in many different applications. To develop the new technology, SciComp needed financial assistance. In 1994, the company received an award from the Advanced Technology Program's (ATP) focused program, "Component-Based Software," for a three-year project that would begin in January 1995.

By the end of the project in 1998, SciComp had successfully developed a software synthesis technology for creating mathematical models that not only made modeling simpler, more accurate, and less expensive, but also immensely shortened the creation effort. Since then, the company has incorporated this technology into SciFinance, a family of financial software products used by the derivative securities industry. In 2004, the company anticipated revenue of approximately $1.5 million from the sale of these products. The ATP-funded project also resulted in two patents and several publications and presentations.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* * * *

Research and data for Status Report 94-06-0003 were collected during March – May 2004.

Mathematical Modeling Is Used across Many Industries

By the mid-1990s, mathematical modeling for computer simulation was increasingly being used by organizations to optimize many scientific applications. For example, it was being used to improve the efficiency of power, refrigeration, and cooling systems. It was also being used in computational fluid dynamics to refine automobile, ship, and aircraft designs quickly, efficiently, and inexpensively and in calculations to enhance engine and turbine efficiency. However, other software modeling methods, which were different from these well-known three-dimensional object-modeling methods, began to gain in popularity during this time.

Partial differential equation pricing models, one form of these new systems analysis tools, were being used by financial institutions. As these institutions entered the arena of complex financial derivatives (hedging contracts), highly paid quantitative analysts known as "quants" programmed, by hand, complex partial differential equation pricing models into computers. While these pricing models were effective, they could take a week or more to program, delaying the ability of derivative traders to do their business as quickly as customers wanted. Since the quants were so highly paid, each derivative model was costly to program.

As the derivative market continued to grow, investment banks, brokerage firms, insurance companies, and

hedge funds increasingly utilized pricing models for complex derivative structures. Because of this increase, these institutions began to seek technology that would assist them in quickly and accurately producing simulation tools to price financial instruments such as futures and options.

New Technology Could Eliminate Programming

SciComp Inc., a start-up firm in Austin, TX, sought to reduce the costs of code development and maintenance. The company proposed to accomplish this by developing software synthesis technology that would eliminate the programming task and create a validated, reusable, interoperable software component. Based on SciComp's existing prototype, researchers had to specify in a computer language only high-level considerations, such as an equation they were trying to solve or variables and domains for which they needed solutions. The required code to solve the mathematical modeling problem would then be automatically generated. This resultant component would be a block of code that could be accessed and used for many applications.

SciComp anticipated that the newly created interoperable software components would significantly increase the productivity of mathematical modelers. In addition, they would be able to quickly validate code without the tedious, time-consuming task of programming. This would give quants more time to experiment with complex models and to find high-quality solutions to application problems. Automatically generated components would also result in more reliable models, because there would be fewer errors in the code. Furthermore, these interoperable components would provide new options for developing a greater variety of models by enabling modelers to combine components in new ways.

SciComp Focuses on the Financial Markets

Initially, SciComp planned to apply its new software development technology in many areas, such as groundwater modeling for environmental cleanup and safe waste storage and air pollution monitoring. However, the company quickly determined that, due to the enormous task of rewriting a customer's outdated code, their efforts would quickly outweigh any revenue gained. So, SciComp turned its attention to financial

areas. One possible application was using partial differential equations to price and value derivative securities. In the early 1990s, the derivative market was quickly growing. SciComp anticipated that, as the market continued to expand, investment banks, brokerage firms, insurance companies, and hedge funds would increasingly turn to automated software algorithms to price complex derivative structures faster and more efficiently.

Software Synthesis Technology Poses High Risk

SciComp's scientific computing goals for the financial industry contained many shortfalls prior to completion. The company did have a proof-of-concept system, SciNapse, which had already demonstrated the basic characteristics of the new technology. However, in order to extend SciNapse, SciComp would have to develop a fundamental specification language that could express a sufficiently general class of problems and solutions while still using specific algorithms. In addition to striking this difficult balance, the company would have to generate intuitive user interfaces for existing numerical and visualization libraries (sets of ready-made software routines) so that the user could quickly find appropriate solutions to standard mathematical modeling problems.

Institutions began to seek technology that would assist them in quickly and accurately producing simulation tools to price financial instruments.

To further develop the SciNapse system, SciComp approached venture capitalists and private firms for additional funding, but found they were unwilling to fund a project that sought to produce a product with no commercial antecedent. In 1994, SciComp finally submitted a proposal to ATP's focused program, "Component-Based Software" and received a three-year award, which began in 1995.

SciComp Successfully Develops Software Synthesis Technology

SciComp's goal was to streamline the mathematical modeling process and increase the productivity of modelers by developing automated technology that

would eliminate the programming task. To achieve this goal, the company would have to meet several technical objectives; these key objectives and SciComp's results are summarized below.

- *Develop intuitive software languages for nonexperts*. **Result:** SciComp redeveloped the specification language used by SciNapse, which significantly increased the language's ease of use. For example, several graduate students were able to learn to write specifications in less than a day. In the past, coding efforts took days, if not weeks.

- *Enable the specification of software performance characteristics as well as the selection of algorithms and components to fit the specifications*. **Result:** By the end of the project, SciComp had developed a technique to extend the algorithms within the specification language to describe desired performance characteristics, such as time (the time it should take for an operation to complete) and space (the amount of computer memory to be used by the algorithm). SciComp also devised ways to select components to meet the modeler's specifications.

- *Make the generated code easily customizable by preserving a record of the original assumptions and design decisions*. **Result:** By the end of the project, the code contained documentation and provided consistency in modeling assumptions. These successes gave future programmers the ability to understand underlying logical premises so that code could be easily modified if necessary.

- *Increase the speed of automating modeling programs (no more than three minutes per page of target code)*. **Result:** By the end of the project, generating code on a state-of-the-art personal computer averaged two minutes per page (one minute per page for simpler codes and three minutes per page for more complex codes).

- *Increase the modelers' productivity by a factor of at least 10*. **Result:** It was difficult to measure increases in modeler productivity, because assessments were made in a noncommercial environment. However, SciComp received several comments from users regarding gains in productivity. For example, a business school

graduate student with minimal programming skills was able to price a complex correlation option in only a few hours using the new technology. In contrast, previously an experienced programmer would have taken approximately a week to manually produce the code required to price the same option.

Focus Turns to Derivative Securities Industry

During the ATP-funded project, SciComp formulated a plan to commercialize approximately 10 applications of its automated mathematical modeling software tool. To develop the plan, the company contracted with a market research firm to conduct a market survey. Based on the results of the survey, SciComp decided to focus its initial commercialization efforts on the financial software market, specifically the derivative securities industry. This industry depends on mathematically complex pricing programs utilizing partial differential equations, which are written by highly paid quantitative analysts. With SciComp's planned software products, analysts would be relieved of the difficult and time-consuming programming involved in developing custom financial instruments.

As SciComp's ATP-funded project came to a close in 1998, the financial software market was rapidly growing, with industry-wide revenue of $200 million per year amid annual increases of 37 percent. SciComp's potential customers were accustomed to spending between $100,000 and $5 million on software purchases. In contrast, SciComp anticipated that its software products would cost between $200,000 and $500,000 per site as the maturing industry became more competitive.

SciComp Develops New Financial Software System

In 1998, shortly after the ATP-funded project ended, SciComp began to incorporate its new technology into a financial software system called SciFinance that could be used to automate the pricing of complex derivative securities. The system included the following tools:

- SciPDE (originally called SciFinance), which could be used to automate the solution of sets of partial differential equations

- SciMC (utilizing Monte Carlo or random probability methods), an alternative technique for solving systems of stochastic (random) equations, which

allowed more dimensions (Dimensions are variables in a situation. For example, time, product type and region are three dimensions of a sales situation.)

- SciValidator (originally called SciRisk), which could be used to restructure derivative portfolios for greater risk and adjusted profits

The software system also included SciNapse, the underlying technology for the SciComp products. SciComp anticipated that these software tools would significantly reduce the time it took to price complex derivative securities and would increase the accuracy of the pricing. The tools could also be used in organizing libraries of modeling software components for derivatives pricing and provide highly developed risk-management analyses.

Interoperable software components would significantly increase the productivity of mathematical modelers.

SciComp planned to sell its products through marketing partnerships, direct sales, and licensing agreements. The company's target customers were quants, financial engineers, traders, risk managers, money managers, and corporate treasurers. By the end of the ATP-funded project, SciComp had established contacts with more than 50 prospects and had identified an additional 2,000.

New Financial Software Is Successfully Commercialized

By April 1998, three months after the ATP-funded project ended, SciComp's software solution, now called SciFinance, was being evaluated at four investment banks, including Chase Manhattan Bank and J.P. Morgan, the largest and second-largest U.S. derivative traders, respectively, and at Union Bank of Switzerland, the third largest derivative trader worldwide. A research laboratory, a university, and three consulting firms were also evaluating the software. In addition to the SciFinance products, SciComp offered its customers consulting services such as custom programming, installation, and support services.

By 1999, SciComp had nine customers in the financial industry, including Merrill Lynch and Bear Stearns. That year, SciComp sold seven one-year licenses for SciFinance. The company also received additional funding of $1.5 million for research and development (R&D) from a venture capital fund. By 2001, SciComp's annual revenue had reached approximately $1 million; however, the company still had not earned enough to recoup all of the costs associated with R&D and product commercialization. But SciComp was optimistic that its revenue would continue to increase.

Shortly thereafter, a series of events occurred that significantly affected the U.S. financial marketplace. The terrorist attacks on September 11, 2001 were followed by numerous corporate fraud cases and a decline in the technology sector. As a result, demand for SciComp's software products fell.

Since 2001, SciComp has continued to develop its products and, as of 2004, the company has five financial software products in its SciFinance solution. In addition to SciPDE, SciMC, and SciValidator, which incorporate the ATP-funded synthesis technology, SciFinance includes the following two products that enhance SciPDE and SciMC:

- SciXL, software for creating custom Excel spreadsheets for mathematical models

- SciIntegrator, software for integrating pricing and hedging models into trading and risk management systems, web sites, and applications with .Com, Java, or .Net wrappers

In 2004, the financial market began to recover, and the volume of derivative securities trading continued to grow, resulting in increased demand for software tools to assist in the pricing of complex derivative structures. Furthermore, there are no direct competitors to the suite of products that SciComp has developed. Because of its automation, the SciComp products are unique within the financial services sector.

SciComp has also increased its sales and marketing efforts by forming several joint venture relationships, including one with CANdiensten, an educational organization and distributor of Mathematica in Europe. SciComp also advertises on the web through

Google.com and in publications such as Wilmott, a magazine for quantitative analysts. The company currently has numerous distributors and support staff locations, including New York, London, Amsterdam, and Australia. In 2004, the company anticipated revenues of $1 million to $1.5 million from sales of SciFinance.

Through its strategic alliances, SciComp plans to continue its development of software tools that incorporate the ATP-funded technology. For example, the company has formed an alliance with the TAF Corporation. SciComp's solutions for rapidly developing and implementing derivatives pricing models now include TAF's PARAGON-enabled product to rapidly accelerate the speed of calculations. In the future, the company would like to explore new applications of its technology, such as in the evaluation and design of other commercial systems including antennas, cell phones, and drug design and delivery.

Conclusion

With ATP's assistance, SciComp successfully developed software synthesis technology that simplifies the mathematical modeling process for financial industry experts by eliminating the programming task and by substantially adding to increases in modeling productivity. Modelers can now quickly generate validated code for models without having to perform the repetitive, time-consuming task of programming. As a result, they now have more time to develop experimental models and find solutions to difficult application problems. With an automated process, models are also more accurate and can be generated at less cost.

Since 1998, SciComp has incorporated its new ATP-funded technology into SciFinance, a family of software products for the derivative securities industry. These products can be used to develop different types of software, without manual programming, for many complex functions, including pricing derivative securities, organizing libraries of derivative pricing, and providing risk-management analyses. By 2001, SciComp's cumulative revenue from sales of these products had reached $2 million; however, due to the terrorist events that year, which significantly affected

the financial industry, sales declined. In 2004, the company experienced increased demand for its financial software products as the market recovers and the company strengthens its marketing efforts. SciComp anticipates 2004 revenues of approximately $1.5 million from sales of these products.

As a result of the ATP-funded project, SciComp was granted two patents, published several papers, and gave presentations on its research.

PROJECT HIGHLIGHTS
SciComp, Inc.

Project Title: Automatic Synthesis of Computer Code for Mathematical Modeling (Automatic Generation of Mathematical Modeling Components)

Project: To develop component software and automated software composition technologies for the field of scientific computing.

Duration: 1/15/1995–1/14/1998
ATP Number: 94-06-0003

Funding (in thousands):

ATP Final Cost	$1,904	87%
Participant Final Cost	282	13%
Total	$2,186	

Accomplishments: With ATP funding, SciComp, Inc. developed component software and a software synthesis technology for creating mathematical models in the field of scientific computing.

SciComp, Inc. also received the following patents for the technology related to the ATP-funded project:

- "System and method for financial instrument modeling and valuation" (No. 6,173,276: filed August 21, 1997; granted January 19, 2001)

- "System and method for financial instrument modeling and using Monte Carlo simulation" (No. 6,772,136: filed January 3, 2001; granted August 3, 2004)

Commercialization Status: Since 1998, SciComp has incorporated its new technology into SciFinance, a software solution for the derivative securities industry. This system of products includes tools that can be used to automate the pricing of complex derivative securities, organize libraries of pricing codes, and provide risk-management analysis.

In 2001, SciComp's revenue from sales of SciFinance reached $2 million; however, due to the severe social and economic setbacks that year, sales were weak in the year following. As of 2004, SciComp offered three software tools in the SciFinance solution that incorporate the ATP-funded software synthesis technology; SciFinance also includes two additional products that enhance SciPDE and SciMC. SciComp experienced greater demand for these products as the market recovered and as the company increased its marketing initiatives. As of 2004, SciComp anticipates revenue of approximately $1.5 million.

Outlook: The outlook is positive for continued demand for SciComp's financial software tools. Since 1990, the volume of derivative securities trading has steadily increased. In 2000, it reached more than $80 trillion. As the derivative market continues to grow, investment banks, brokerage firms, insurance companies, and hedge funds will utilize pricing models for complex derivative structures and are likely to seek tools that will assist them in quickly and accurately producing simulation tools for these models. In 2004, SciComp had few competitors that provided these software products.

Composite Performance Score: * * * *

Focused Program: Component-Based Software, 1994

Number of Employees: 1 employee at project start, 5 as of November 2004

Company:
SciComp, Inc.
5806 Mesa Drive
Suite 250
Austin, TX 78731

Contact: Dr. Elaine Kant
Phone: (512) 451-1050

Publications:

SciComp published its findings in the following:

- Randall, C., E. Kant, and S. Kostek. "Automatic Synthesis of Financial Modeling Codes," *Proceedings of the International Association of Financial Engineers First Annual Computational Finance Conference*, Stanford, CA, August 23-24, 1996.

- Akers, R., E. Kant, C. Randall, S. Steinberg, and R. Young. "SciNapse: A Problem-Solving Environment for Partial Differential Equations," *IEEE Computational Science and Engineering*, 4:3, 32-42, 1997.

- Randall, C. and E. Kant. "Numerical Options Models Without Programming," *Proceedings of the IEEE/IAFE Conference on Computational Intelligence for Financial Engineering*, New York, NY, March 23-25, 1997.

PROJECT HIGHLIGHTS
SciComp, Inc.

- Kant, E. and S. Steinberg. "Automatic Program Synthesis from Abstract PDE Specifications," *Proceedings of the 15th IMACS World Congress on Scientific Computation, Modeling, and Applied Mathematics*, Berlin, Germany, August 24-29, 1997.

- Randall, C., E. Kant, and A. Chhabra. "Using Program Synthesis to Price Derivatives," *Journal of Computational Finance*, 1:2, 97-128, 1998.

- Brown, G.W. and C. Randall. "If the Skew Fits," *Risk Magazine*, 12:4, 62-65, 1999.

- Gatheral, J., Y. Epelbaum, H. Jining, K. Laud, O. Lubovitsky, E. Kant, and C. Randall. "Implementing Option-Pricing Models Using Software Synthesis," *Computing in Science & Engineering*, 1:6, 54-64, 1999.

- Akers, R., I. Bica, E. Kant, C. Randall, and R. Young. "SciFinance: A Program Synthesis Tool for Financial Modeling," *AI Magazine*, 22:2, 27-41, 2001.

- Akers, R., P. Baffes, E. Kant, C. Randall, S. Steinberg, and R. Young. "Automatic Synthesis of Numerical Codes for Solving Partial Differential Equations," *Special Issue on Non-Standard Applications of Computer Algebra, Mathematics and Computers in Simulation*, Elsevier Science Publishers, North-Holland (to be published).

Presentations:

SciComp also disseminated knowledge gained during the project through the following presentations:

- Kant, E. and S. Steinberg. "Automatic Program Synthesis from Abstract PDE Specifications," The 15th IMACS World Congress on Scientific Computation, Modeling, and Applied Mathematics, Berlin, Germany, August 24-29, 1997.

- Randall, C. and E. Kant. "Numerical Options Models Without Programming," The IEEE/IAFE Conference on Computational Intelligence for Financial Engineering, New York, NY, March 23-25, 1997.

- Randall, C., E. Kant, and S. Kostek. "Automatic Synthesis of Financial Modeling Codes," The International Association of Financial Engineers First Annual Computational Finance Conference, Stanford, CA, August 23-24, 1996.

Titan Systems (formerly Intermetrics)

Electronic Transfer of Healthcare Data via the Continuously Available Medical Care (CAMC) Software

When a patient's medical data are transferred between the doctor and the patient via their personal computers (PCs), the benefits can include fewer office visits and the ability to diagnose remotely. This idea has been discussed for many years in medical communities, but it was not until the 1990s that it became feasible. At that time, several technological advances were available that could help to enable this medical data transfer: the development of high-speed data transmission over landline telephone circuits; increased data computation capacity and storage in PCs; and improvements in multimedia, such as the CD-ROM data storage tool.

Intermetrics, a 25-year-old software design company, sought to revolutionize medical data transfer between patient and provider by developing new and specialized software for that purpose. Due to the difficulty of obtaining funding outside its own corporate resources, Intermetrics applied for and won an Advanced Technology Program (ATP) award to develop the Continuously Available Medical Care (CAMC) software. Intermetrics received this award under the ATP focused program, "Information Infrastructure for Healthcare," in 1994.

Although potential buyers, such as the Boston University Medical Center Pilgrim Healthcare Plan, were impressed with the demonstration product, two factors forestalled its development. First, rapid advancements were made in standardized script languages used by web servers, which made the customized script used by the CAMC software obsolete. Second, HealthVision, a healthcare consulting firm, eventually acquired the CAMC software. They did not intend to pursue disease management software development, and therefore, no products have been marketed based on the technology developed during this ATP-funded project.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
No Stars

Research and data for Status Report 94-04-0040 were collected during April – June 2004.

Chronically Ill Population Can Be Served by Automation Advances in Home Healthcare

In the mid-1990s, more than 25 million homebound or limited-mobility Americans suffered from the five leading chronic diseases: heart disease, cancer, diabetes, hypertension, and chronic obstructive pulmonary disease. Most of these patients faced frequent and costly visits to doctors or clinics. A 1994 study by Boston University indicated that 75 percent or more of these office visits could be replaced by efficient and comprehensive telemedicine, which involved transmitting patient data over phone lines instead of gathering these data during an office visit.

Intermetrics, a 25-year-old company with a successful record in software design, envisioned new and unique software that could provide a telemedicine solution for thousands of homebound patients. Because funding was very difficult to obtain for this complicated technology development, the company submitted a proposal and received funding from ATP to develop a software tool that would help patients minimize the cost and strain of office visits by providing them (or their caregivers) with a way to transmit vital medical data from their home, nursing home, or assisted living facility. ATP provided the funding as part of the "Information Infrastructure for Healthcare" focused program of 1994. The patient data would be transmitted to a care provider, who would give feedback and

further treatment information. Testing and developing the software, hardware, and demonstration product would be complicated and difficult. ATP helped to facilitate collaboration with Boston University, which would evaluate the prototype's development. To develop the software, Intermetrics subcontracted with Lazo, Gertman, and Associates.

A 1994 study by Boston University indicated that 75 percent or more of doctor's office visits could be replaced by efficient and comprehensive telemedicine.

The team's proposed product, called the Continuously Available Medical Care (CAMC) software, would be installed on both the doctor's and the patient's personal computers (PCs). The patient or the patient's caregiver would transmit medical data to the doctor's office that would normally be collected in an office visit. The software would then analyze the data on the doctor's PC. The doctor's recommendation for treatment, stored in a database, would be transferred back to the patient's PC. During this process, the doctor would also be available online in real time to answer any questions. The software designers' vision was that the patient could report to the doctor, through a telephone line, such data as heart rate, blood pressure, body temperature, heart and lung sounds, and other data as necessary. The CAMC software could access a doctor's computer to report the data and request the appropriate treatment.

Advancements Achieved in Data Transfer Using PCs

The advantages of telemedicine have been well known for years in the medical sector. At the time of Intermetrics' proposal, several factors indicated that it was the right time to explore CAMC technology, including the following:

- PCs had become more powerful with improved memory and data computation capacities.

- Multimedia advances could assist with CAMC functions; for example, CD-ROMs could enable a user to consult a symptom library.

- Videoconferencing could provide a real-time link to the caregiver in a nursing home or the doctor's site. For example, a camera could transmit the current condition of a patient's swollen limb to a doctor.

- For communication between the doctor and the homebound patient, high-speed telephone lines were available. While the lines were not ideal for videoconferencing, they were becoming increasingly cost effective.

- The legislative climate was receptive to healthcare reform. For example, the Veterans Administration could benefit from reform by paying out less in claims by reducing office visits.

Intermetrics planned to market the CAMC software as three products: CAMC Premier for private patients, CAMC for Congregate (Assisted) Living, and CAMC for Nursing Homes. While private patients would be expected to pay for the CAMC service with their own resources, they would experience future cost savings through a significant reduction in the number of office visits they needed. Furthermore, assisted living facilities and nursing homes would pay for the software and updates themselves. (This cost factor may have contributed to their subsequent reluctance to purchase the product.)

The major risk and technical difficulty in developing the CAMC software for these three markets was the customization that was required for each client, which would depend on the patient's medical profile. The database residing on the doctor's PC needed to be customized for each patient's assessment according to the patient's specific illness. For example, a diabetic would need a customized response that was different from a patient with heart disease, because disease-specific symptoms would be monitored, analyzed, and reported by the CAMC software.

Team Defines the CAMC Software Tool Suite Functions

In developing the CAMC software, Lazo, Gertman, and Associates would contribute expertise from its prior prototype development experience in non-CAMC market research. Intermetrics would contribute its expertise in designing, implementing, and standardizing

the script language that the CAMC software used in order to perform its functions. Boston University Medical Center, a third participant in the project, would help to define the requirements for the three tools that would be included in the software's tool suite. These tools would perform the following functions:

- The Data Entry Tool would allow the caregiver to enter patient data into the CAMC software.

- The Plan Tool would use the data that were entered by the Data Entry Tool. The Plan Tool transferred therapeutic care plans to the patient's PC.

- The Customization Strategy Tool would collect information on the patient's condition that the doctor needed to monitor. This tool included a sophisticated questionnaire used to capture information that enabled the software to accurately track the patient's condition, depending on his or her illness.

During the project, the Customization Strategy Tool was the most challenging tool to develop and maintain, due to the large database of patient information that required analysis by the CAMC software. Consequently, this tool required the most testing and code rewrites.

Intermetrics Identifies CAMC Software Markets

Intermetrics' commercialization plan for the CAMC software focused on installing it at institutions such as the Veterans Administration, health maintenance organizations, homecare companies, and state Medicaid providers. Lazo, Gertman, and Associates would retain the rights to commercialize any healthcare applications for the product, while Intermetrics would retain any rights to applications not related to healthcare.

Competing Technology Challenges CAMC Software Development

Intermetrics made efforts during the project to keep pace with the rapid advancements in web-based data transfer technology. For example, in the fourth quarter of 1996, the company contacted Continental

Cablevision to arrange an agreement whereby Continental would transmit the data between patients and doctors over a cable transmission line, which has a higher capacity than a telephone line. However, Continental lost interest in the project when it realized that current laws did not protect Continental from potential liabilities arising from transmitted data.

In this same timeframe, Congress passed the 1996 Health Insurance Portability and Accountability Act (HIPAA). The practical effects of HIPAA neither helped nor hindered CAMC's marketing prospects, as the law initially had no enforcement power. In general, it was unclear to HMOs and to doctors how they were to implement HIPAA. Moreover, CAMC already had built-in, password-controlled security in its software. The appropriate level of security was invoked depending on who accessed the software, so access to personal patient information was controlled, which conformed to one of HIPAA's intents.

The major risk and technical difficulty in developing the CAMC software was the customization that was required for each client.

Before the project ended in April 1997, Intermetrics demonstrated the CAMC first-generation software for the Harvard Pilgrim Healthcare Plan, the largest HMO in four New England states. Pilgrim evaluators thought the product had potential, but subsequently Lazo, Gertman, and Associates were not successful in selling a product to Harvard Pilgrim. In the last quarter of the project, Intermetrics delivered the tool suite and the CAMC software library to Lazo, Gertman, and Associates, in keeping with their mutual agreement that Lazo would have commercialization rights to the software. But delays due to technical difficulties forestalled scheduled field trials.

In retrospect, another factor contributing to the failure of Intermetrics' proposed software was the arrival of the web-based server near the end of the project. By that time, the web-based server had become mature enough to challenge the PC-based server because it used a simpler script language, which facilitated improved record access. CAMC developers could not compete with these advancements, which greatly

accelerated the obsolescence of the CAMC software. Unlike the CAMC server on a doctor's PC, the web-based server allowed several patients and doctors to access information simultaneously. This alone was a significant advancement. Internet script language is more standardized than Oracle's, which is what Intermetrics was using to transfer data between the patient's and the doctor's PC.

After the conclusion of the project, Lazo, Gertman, and Associates pursued plans to update the CAMC software with web-enabled script language. The company used a 1997 Small Business Innovation Research grant to pursue web-enablement of the software, which they achieved that same year. The company then changed its name to U.S. Carelink to maximize the software product's marketing prospects, but could not persuade any of its original target clients to buy the software. HealthVision then bought U.S. Carelink in 2001. Through this acquisition, HealthVision hoped to accelerate its entry and dominance into the new frontier of telemedicine. HealthVision did not want to invest further resources, based on a shift in commercial strategy, to upgrade the web-enablement technology to a commercially competitive status in a rapidly changing technology environment. As of 2004, HealthVision was not pursuing any disease management clinical applications, which was the focus of the original CAMC software. The primary research company on the project, Intermetrics, was eventually acquired by Titan Systems in March 2000. Although Titan Systems acquired universal rights to the CAMC software, it has not pursued any applications related to the original technology.

Conclusion

The advancements in personal computers and improvements in data transfer over telephone lines inspired Intermetrics to team with Lazo, Gertman, and Associates to create one of the first software packages for telemedicine data transfer. Their proposed product would create an electronic link between the homebound or limited-mobility patient and a doctor that would reduce the frequency of office visits and speed diagnoses. The team designed software products for three patient sectors: private, assisted living, and

nursing homes. Despite a successful prototype demonstration at Harvard Pilgrim Healthcare Plan, the largest HMO in New England, the product's customized script language became obsolete by rapid advancements in Internet script language and the web-based server. Lazo, Gertman, and Associates successfully added web enablement to the Continuously Available Medical Care (CAMC) software after the project ended. Although they changed their name to U.S. Carelink in an effort to market the product, the company was unsuccessful in selling the software. U.S. Carelink did not want to risk further corporate resources to upgrade web enablement to a truly competitive status in the rapidly advancing world of Internet electronic commerce. HealthVision acquired U.S. Carelink, but did not pursue the technology. Titan Systems, which eventually acquired Intermetrics, also had no interest in upgrading the obsolete technology.

Although this technology did not succeed in the mid-1990s, the need still exists. As of early 2004, President Bush had promised to appoint a national health information technology coordinator at the Department of Health and Human Services. The goal is to set technical standards for the switch from paper to electronic medical records by the end of the year, so that doctors and hospitals can share patient records nationwide.

PROJECT HIGHLIGHTS
Titan Systems (formerly Intermetrics)

Project Title: Electronic Transfer of Healthcare Data via the Continuously Available Medical Care (CAMC) Software (Enterprise Tools for the CAMC Home Healthcare System)

Project: To develop a script language and a related suite of software tools to facilitate the process of developing customized home healthcare workstations for homebound or limited-mobility, chronically ill patients.

Duration: 12/15/1994 - 3/17/1997
ATP Number: 94-04-0040

Funding (in thousands):

ATP Final Cost	$1,761	71%
Participant Final Cost	729	29%
Total	$2,490	

Accomplishments: With ATP funding, the team of Intermetrics and Lazo, Gertman, and Associates developed a successful prototype device that transferred data between a patient's computer and a caregiver's computer via a high-speed data access phone line.

Commercialization Status: This product was not commercialized. The intellectual property was acquired by HealthVision, which chose not to further develop it.

Outlook: The outlook for this technology is weak due to product obsolescence caused by rapid advances in Internet technology for transfer.

Composite Performance Score: No Stars

Number of Employees: 6 at project start, 0 as of June 2004

Focused Program: Information Infrastructure for Healthcare, 1994

Company:
Titan Systems (formerly Intermetrics)
3033 Science Park Road
San Diego, CA 92121-1199

Contact: Dr. Woodrow Vandever
Phone: (781) 906-8414

Subcontractors:
Lazo, Gertman, and Associates, Inc. (This company was acquired by HealthVision.)
Irving, TX

Boston University Medical Center
Boston, MA

Research and data for Status Report 94-04-0040 were collected during April – June 2004.

Xerox Corporation Palo Alto Research Center

Improving Software Efficiency Through Reusable Components

Software for large, computer-driven systems was generally proprietary and highly customized in the mid-1990s. Typically, about 80 percent of each application's code was original, which meant that development and maintenance costs were high. Buyers wanted more from these programs; they wanted software that could be used in more than one application and that was easier for programmers to work with, features that would improve the programmers' productivity. Researchers at the Xerox Palo Alto Research Center (PARC) thought they could solve the problem by making software more modular, which would improve compatibility among software applications.

In 1994, PARC applied to the Advanced Technology Program's (ATP) "Component-Based Software" focused program. With ATP's cost-shared award, the two-year project began in January 1995. As researchers developed prototype applications, they began to extract parts of programming code reflecting concerns (problems that a computer program tries to solve) that cut across the entire system and to make these concerns, or aspects, separate modules. Aspects affect a programmer's choices throughout a software application, such as logging changes to data entries. This approach differed radically from earlier attempts at modularity. The PARC researchers called their approach aspect-oriented programming (AOP) and later developed products that incorporated its principles. At the same time, Java, a new programming language used to write Internet-based material, was gaining widespread popularity. AOP complemented Java because both technologies made software more modular.

When ATP funding ended in December 1997, PARC began working with the Defense Advanced Research Projects Agency to further develop AOP. PARC created a general-purpose programming language, AspectJ, which it patented. In 2002, the company made this technology freely available by transferring it to eclipse.org, an open-source project sponsored by IBM.

By 2004, AOP was well recognized in the computer industry and was taught at more than a dozen universities in North America and the United Kingdom. Eight patents emerged from the ATP-funded project. More than 3,250 articles or books have been written about AOP. In 2003, JavaWorld named AspectJ best new product or process using Java, and IBM uses AspectJ in developing new software products. The outlook for the technology is very strong.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* * * *

Research and data for Status Report 94-06-0036 were collected during October – December 2004.

Need for Reusability Drives Search for More Efficient Programming

In computer programming, high-level code enables programmers to use single statements to represent large chunks of binary digital code. In the mid-1990s, programmers were writing this kind of code with object-oriented programming. Object-oriented programming defined a computer program as a collection of individual units, or objects, as opposed to an earlier view in which

a program was essentially a list of instructions to the computer. Each object can receive messages, process data, and send messages to other objects. Messages can be handled by one or more pieces of code, and programmers can create relationships between one object and another so that objects can inherit characteristics from other objects. For example, a system requirements engineer might specify a bank account with the associated functions of depositing, withdrawing, and providing a balance. A system designer would describe an object "bank account," which the programmer would implement in code. Object-oriented programming made it easier to create and extend complex applications such as graphical user interfaces (GUIs), operating systems, and distributed applications (for example, browsers that run on more than one computer and communicate through a network).

Programmers were also increasingly using modules, or components that could be connected to each other. Modularity enables programmers to replace or add a component without affecting the rest of the system. With component-based software, programmers could develop custom applications without concerning themselves with the details of implementation because those details were hidden. However, hiding implementation code also hid inherent problems, which meant that resolving these problems was difficult to impossible, resulting in slow and inefficient systems.

Gregor Kiczales, a computer scientist at the Xerox Palo Alto Research Center (PARC), wrote that conventional computer-industry wisdom considered it "essentially impossible for code to be both high-level and efficient, except in very specific cases that usually involve removing any hope of reusability. The programming world is thus divided into two basic camps, one that espouses elegant high-level code and the other that promotes inelegant but highly efficient code."

Xerox Corporation produces copiers, printers, image-processing systems, and desktop publishing systems that all contain computers. Xerox was interested in developing more powerful products that could be tailored to its customers' individual needs. Because that step was impossible without reusable code, the company turned to PARC. Since its founding in 1970, PARC had invented object-oriented programming and

many of the technologies and products now considered standard in computing: personal computers, what-you-see-is-what-you-get (WYSIWYG) monitor display, graphical user interfaces, Ethernet networks, the mouse, and the laser printer.

Programming Languages Could Not Produce Reusable Components

There had been previous experiments in producing reusable components. For example, researchers in Japan had developed programming languages and operating systems that allowed programmers to control the behavior and location of objects, but these projects' output had not been commercialized. Researchers in France had developed control over some issues in implementing networks, but only for one highly specific use.

Separating concerns such as error-checking and handling, synchronization, and performance would improve the speed, quality, and flexibility of core code.

PARC contended that the programming then in existence could not produce software components that were compatible with other components; that is, they were not "plug and play" components. PARC hypothesized that the fundamental problem was the hidden implementation and layers of abstraction. PARC wanted to prove this through prototype applications; beyond that, it wanted to develop general principles and techniques for industry programmers. In addition, PARC wanted to achieve separation not just between functionality and implementation, but also among a number of different implementation issues.

Because the proposed prototype, principles, and techniques were radical and high risk, PARC applied for ATP funding in 1994 under the focused program, "Component-Based Software." With a larger staff made possible by the two-year award, they proposed to develop a semantic framework that describes a component's function and a separate implementation framework that prescribes how to put the component into use. The PARC team intended to articulate the principles of separation of implementation and then develop technological applications if experiments showed the principles to be sound.

Research and Business Outlooks Were Clouded

When the ATP-funded project began in January 1995, PARC faced skepticism in the research community, which predicted that the proposed solution would make code and systems less modular or flexible. There was no mechanism to open up a module to expose internal structure. It was thought that the inside of a module had to remain completely hidden for systems to be stable, robust, and flexible.

In addition, the outlook for commercialization was problematic. It was felt that the business community would be reluctant to train its programmers in a new type of programming unless there was a clear financial advantage to retraining employees, shutting down systems, and experiencing other downtime that comes with changing software. Conventional wisdom held that retraining an experienced programmer in object-oriented techniques required 6 to 18 months before that programmer was fully productive.

The PARC researchers assumed that the major problem in developing reusable components occurred when a programmer wanted to reuse some or all of the semantic code, but not necessarily all of the implementing code. As research under the ATP award began, they scaled up the project, centering their research on two customized prototypes. The prototypes included languages that application experts could use to define specific applications in specific areas: an image-understanding language for certain kinds of image-processing applications and a sparse matrix language for computations common to forms of scientific and numerical computing.

About halfway through the project, the researchers realized that separating semantic code from implementing code would not solve the problem they had set out to solve. They developed a new hypothesis based on their understanding that many of the objects were implemented in similar or duplicated code and decided to explore the difference between core concerns and cross-cutting concerns. A concern is any problem that a program tries to solve. Programs address core concerns (such as credit card billing, or sending email). Cross-cutting concerns do not relate to core concerns directly, but a program cannot be executed without addressing cross-cutting concerns. Often when programmers changed a feature of a cross-

cutting concern, they had to recompile source files and check code for consistency. The team began to isolate the cross-cutting concerns, such as error-checking and handling, synchronization, and performance optimization. Separating these concerns, or aspects, the team hypothesized, would improve the speed, quality, and flexibility of core code.

Aspect-Oriented Programming Is Born

The team filed two patent applications related to sparse matrix code in 1995. Sparse matrix code enabled users to write high-level code and annotate it to make implementation more efficient. As a result, reusable components could match the speed of customized applications and were shorter and less complex.

In 1996, the PARC team sponsored a conference, Reflection '96, to present their findings, which they called Open Implementation Analysis and Design methodology. They next presented their findings at several international conferences. At this point, the PARC researchers realized that further development would take more time and resources than could be funded by the ATP award. Therefore, although the ATP project was funded through December 1997, in 1996 the team submitted a proposal to the Defense Advanced Research Projects Agency (DARPA) for assistance to continue work after the ATP-funded project ended.

Although others had been doing research in the same general area, the PARC team was recognized as the first to articulate the technology, which they named aspect-oriented programming (AOP). Just as object-oriented programming added to the programming that preceded it, AOP added to object-oriented programming rather than replacing it.

Over the course of the ATP-funded project, interns from Northeastern University, the University of Washington, Indiana University, and Massachusetts Institute of Technology tested ways to use AOP and developed best practices and guidelines. In August 1996, the PARC team reported that they had introduced AOP to the research community and were promoting it through papers, workshops, and presentations. They filed another patent application related to a high-level language for AOP in late 1996.

Towards the end of the ATP-funded project, researchers started designing a general-purpose tool that they named AspectJ. This tool enables programmers to define features that reflect crosscutting concerns (such as security or dependability) needed for a system and, through a compiler, to place those features throughout the code. Through an alliance with PARC, the University of British Columbia systematically evaluated AspectJ in use beginning in the summer of 1997. In August 1997, PARC signed a contract with DARPA as a result of its proposal a year earlier, for a $1.3 million, three-year project. The project would explore whether AOP was suitable for use in a decentralized system so that end users could analyze and distribute information if part of the system were destroyed or if it could be used in smart-matter applications, which enable systems to adapt immediately and autonomously to changes in their environment. During this DARPA-sponsored follow-on research, PARC further developed AspectJ and readied it for dissemination.

Knowledge of AOP Spreads

The University of British Columbia evaluators and other users found AspectJ to be simple and straightforward. Components could be plugged into a software program, greatly reducing the cost and time of installation. PARC researchers were careful to create a product with a 15-minute adoption profile; that is, one that a programmer could very quickly learn alone, without further training. This profile assuaged businesses' qualms that adopting AOP would result in significant downtime.

Aspect oriented programming's modularity can help mass-merchandise web sites deliver faster, more reliable service, at a lower cost, and with greater customization.

The team benefited greatly from Sun Microsystems' introduction of Java in 1994 and its nearly instant success. Java was designed as an object-oriented programming language, using small programs downloaded from the World Wide Web to write Internet-based material that incorporated animation, sound effects, calculators, and other special effects. Java accelerated the expansion of the Internet into a flexible method of communication. AOP complemented Java, because it allowed programmers to improve productivity and quality immediately. As software becomes more complex, AspectJ allows programmers to recompose large and complex software into simpler, better targeted, higher quality products.

PARC released AspectJ to the public in 1998. Since then, "it has been available for downloading from the Internet and has been used by thousands of software developers. The only competing technology is manually installing components in a program. The costs of doing this are so prohibitive that it is not often done," according to *Benefits and Costs of ATP Investments in Component-Based Software* (NIST Report GCR 02-834).

By the end of 1999, PARC had applied for five more patents, including one for AOP. By 2001, AOP was becoming more widely known in the industry. The Association for Computing Machinery wrote that AOP "promises simpler system evolution, more comprehensible systems, adaptability, and easier reuse." AOP makes the aspect code and the target application programming easier to understand, which is especially important as software becomes more complex and as programmers are unlikely to be familiar with the intricacies of specialized algorithms.

To win broad acceptance for the new technology, PARC opted to retain the patents but make the technology open-source. In December 2002, PARC transferred AspectJ to eclipse.org, an open-source project under the sponsorship of IBM. Since then, AspectJ has become part of Java and IBM's WebSphere Suite. In June 2003, AspectJ won the *JavaWorld* Editors' Choice Award for the Most Innovative Product or Technology using Java.

According to IBM computer scientist Adrian Colyer, quality of service and serviceability were originally bundled on the Websphere platform. AspectJ allowed IBM's programmers to make quality of service and serviceability into modules that IBM can sell separately. Several of IBM's product teams incorporate AOP in their projects. In addition to developing a more modular and flexible code, some teams use aspects to enable replacement of policies (such as access or security policies) on a per-customer or per-environment basis, something that was not possible before.

In 2003, IBM started the AspectJ Development Tools (AJDT) project to provide support for developing AspectJ applications in eclipse.org's development environment. AJDT provides the tools needed to make day-to-day development with AspectJ practical for IBM development teams, as well as for developers outside IBM. AJDT has also been integrated into IBM's Rational Software Development Platform tools based on eclipse. AJDT is a separately downloaded application that can be added onto the products rather than being included in the product itself. According to Colyer, this enables both IBM and its customers to use AspectJ for enterprise application development.

IBM also uses AOP to split off the best components from its middleware (software that intermediates between two or more applications) and put them together in new ways to create more modular and flexible solutions. Typically, product teams working in this way can use common components across many environments, where previously some duplication would have been required. This ability saves several person-months of development time.

In March 2004, IBM Vice President for Software Group Strategy and Development Daniel Sabbah said, "AOP will simplify the delivery and service of high-quality software, deliver new solutions for our customers' development requirements, create opportunities for customers to add value to their software, and accelerate new initiatives at the heart of IBM's software strategy."

ATP Award Crucial to Project's Success

AspectJ is entering the mainstream of programming tools, although exact figures on usage are hard to determine because users do not have to buy the application. Six books have been published specifically about AspectJ, including Japanese and Spanish versions. AOP and AspectJ have been cited in more than 3,000 articles, papers, or presentations. PARC team leader Gregor Kiczales estimates AspectJ has between 5,000 and 10,000 users and says that AspectJ is growing as fast as it possibly can.

AOP is taught in 15 to 20 North American and United Kingdom universities. Former PARC team member Cristina Lopes continues her research in AOP as a professor at the University of California at Irvine. Xerox

has patented the project's two prototypes along with AspectJ. The PARC team members have made numerous presentations, and PARC launched an AspectJ web page.

Although AspectJ was not commercialized because it is offered as a free download from the Internet, it is widely used as a tool in revenue-generating business applications. The interest in and adoption of AOP and AspectJ continues to expand both within IBM and externally, according to Colyer. Opportunities to exploit AspectJ appear and new project teams form at IBM every month.

None of this would have happened without ATP funding, according to Kiczales. Even within PARC, the idea was radical, so that receiving ATP funding was the difference between going ahead or canceling the research. In addition, PARC's relationship with ATP forced the research team to think early on how their research might lead to commercialization. Although none of the originally envisioned products were developed, ATP encouraged the team to think about the commercial problems that an advanced technology would solve, which for many software researchers was an unheard-of approach. That perspective led the team to re-target the work to the Java platform and AspectJ in the late stages of ATP funding.

As of 2004, AOP had experienced one of the fastest paths in the software industry from research to implementation; furthermore, it appeared to be slowly changing the nature of component-based software. It is recognized that computer companies can make money in the short run by selling specific components and that tools and infrastructure needed for a full-scale market take longer to reach profitability. Because of this, in Kiczales's view, the private sector often lags in developing such tools and infrastructure. ATP funding, according to Kiczales, "encourages companies to focus on the longer term technologies such as AOP that are needed for a mature, component-based software market."

"We are in the early stages of understanding the full potential of Aspect Oriented Software Development," wrote Gary Pollice, of Worcester Polytechnic Institute, in 2004. "Aspect-oriented technology might allow us to do a better job of maintaining systems as they evolve. AOP would let us add new features, in the form of

concerns, to existing systems in an organized manner. The improvements in expressiveness and structure might allow us to keep systems running longer, and to incrementally improve them without incurring the expense of a complete rewrite. Using an AOP language, we might be able to test application code automatically without disturbing the code. This would eliminate a possible source of error."

Kiczales compares the benefits of AOP to those of Intel Inside. The average computer user does not understand or care about Intel's microprocessors or about aspects, but both technologies make applications work faster and more smoothly. AOP's modularity can help mass-merchandise web sites deliver faster, more reliable service, at a lower cost, and with greater customization.

Conclusion

As computer software grows more complex, programming becomes more difficult and the code produced by the programming is often unwieldy. However, the end users continue to seek higher productivity and flexibility; ultimately, they want to be able to reuse expensive software. Researchers at the Xerox Palo Alto Research Center (PARC) were looking at ways to address these concerns. They applied for and won an ATP award under the "Component-Based Software" focused program that allowed them to pursue their research on reusable software components with a larger team. In 1995, the PARC team looked at ways of separating the implementing code from the core source code. After two experiments, they modified their hypothesis to extract crosscutting concerns, or aspects, and write code to make these aspects into separate modules. This led them to formulate a new paradigm for computer software engineering, called aspect-oriented programming (AOP). In follow-on research sponsored by the Defense Advanced Research Projects Agency, the PARC team developed a highly successful product, AspectJ, which they transferred to IBM's eclipse.org, an open-source project. AspectJ is now part of the Java software platform and can be downloaded from eclipse.org. IBM is using AspectJ and AOP in its product development.

The effects of this new way of programming are just beginning to be realized. The technology has won one award and has been described in 6 books, dozens of presentations, and more than 3,000 articles. Universities in the United States, Canada, and the United Kingdom are teaching courses in AOP, and the computer industry is beginning to use it to develop new software. IBM, in particular, has expressed confidence that AOP will both simplify and improve high-quality software. The outlook for this technology is strong.

Project Title: Improving Software Efficiency Through Reusable Components (Reusable Performance-Critical Software Using Separation of Implementation Issues)

Project: To develop a component software technology that separates the semantic details of a component from the implementation details in order to support the use of software components and automated software composition for high-performance applications.

Duration: 1/1/1995-12/31/1997
ATP Number: 94-06-0036

Funding (in thousands):

ATP Final Cost	$1,670	57%
Participant Final Cost	1, 275	43%
Total	$2,945	

Accomplishments: With ATP funding, the Xerox Palo Alto Research Center (PARC) accomplished the following:

- Developed a new programming technique called aspect-oriented programming (AOP)

- Developed two prototype applications of specialized computer languages

- Developed AspectJ, an open-source language that extends Java; it is being further developed and used in IBM's software applications and by many others

In June 2003, AspectJ won the JavaWorld Editors' Choice Award for the Most Innovative Product or Technology Using Java.

PARC received the following patents for technologies resulting from the ATP project:

- "Tools for efficient sparse matrix computation" (No. 5,781,779: filed December 18, 1995; granted July 14, 1998)

- "Ordered sparse accumulator and its use in efficient sparse matrix computation" (No. 5,983,230: filed December 18, 1995; granted November 9, 1999)

- "High-level loop fusion" (No. 5,822,593: filed December 6, 1996; granted October 13, 1998)

- "Software constructs that facilitate partial evaluation of source code" (No. 6,199,201: filed August 3, 1998; granted March 6, 2001)

- "Aspect-oriented programming" (No. 6,467,086: filed July 20, 1999; granted October 15, 2002)

- "Aspect-oriented system monitoring and tracing" (No. 6,473,895: filed July 20, 1999; granted October 29, 2002)

- "Integrated development environment for aspect-oriented programming" (No. 6,539,390: filed July 20, 1999; granted March 25, 2003)

- "Software constructs that facilitate partial evaluation of source code" (No 6,631,517: filed November 2, 2000; granted October 7, 2003)

Commercialization Status: The ATP funded AspectJ is now used in a significant percentage of IBM's new products and is an open-source platform. PARC transferred AspectJ to the open-source eclipse.org project in December 2002.

Outlook: The outlook for AOP is strong. As universities include it in their curricula, more computer scientists will gain proficiency and will find ways to use it in designing programs. IBM is aware of its utility and uses it in the majority of its new software products; other software developers are likely to follow suit. AspectJ has also been designed to conform to the "15-minute rule": software engineers can download it and become productive within 15 minutes.

Composite Performance Score: * * * *

Focused Program: Component-Based Software, 1994

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Xerox Palo Alto Research Center
3333 Coyote Hill Road
Palo Alto, CA 94304

Contact: Eric Steffensen
Phone: (415) 812-4073

PROJECT HIGHLIGHTS
Xerox Corporation Palo Alto Research Center

Publications: Of the 6 books and more than 3,250 articles on AspectJ or AOP, the following is a sample:

- Kiczales, Gregor. "Beyond the Black Box: Open Implementation." *IEEE Software*, 13(1), January 1996: 8-11.

- Kiczales, Gregor. "Aspect-Oriented Programming." *ACM (Association for Computing Machinery) Computing Surveys* 28(4es), December 1996: 154.

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Development of New Knowledge and Early Commercial Products and Processes, 3rd 50 of Status Reports

Table A-1: Advanced Materials and Chemicals; Table A-2: Biotechnology; Table A-3: Electronics, Computer Hardware, or Communications; Table A-4: Information Technology; Table A-5: Manufacturing

Table A-1. Advanced Materials and Chemicals

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
ABB Lummus Global, Inc. (formerly ABB Lummus Crest)	95-05-0034	Developed a new, environmentally superior process to manufacture alkylate, an ideal unleaded gasoline additive, using solid-acid catalysts	As of 2005, the joint venture partners were seeking commercial opportunities to build new solid-acid alkylation plants
Advanced Refractory Tech	95-01-0131	Developed a diamond-like nanocomposite (DLN) coating technology. The company established improved manufacturing techniques for DLN films and developed several applications, such as electrosurgical blades and flat panel displays	A number of products with DLN coatings are currently being sold. These include components that are used in manufacturing CDs, DVDs, polyethylene terephthalate juice bottles, and metal cans and components used in semiconductor cluster tools
Air Products and Chemicals, Inc.	93-01-0041	Developed ceramic-steel seals and processes to remove contaminants from oxygen	The company is continuing its research and development (R&D) into their prototype air-separation unit for producing high-purity oxygen so that future commercialization may be possible. However, the company does not intend to pursue commercialization initiatives until a 30-percent decrease in production cost is achieved
Automotive Composites Consortium (a Partnership of DaimlerChrysler [formerly Chrysler], Ford and General Motors)	94-02-0027	Developed a composites-manufacturing process called Structural Reaction Injection Molding (SRIM) for f producing large automobile structural parts, such as the box of pickup trucks	Commercialized the access door and tail cone for the Air Force C-17 cargo plane by Boeing, firefighter helmet shells by Lion Apparel, the inner tailgate sections for the GM Cadillac Escalade EXT hybrid SUV beginning in 2001, the load floor sections for the "Stow 'n Go" system to fold down second-and third-row seats in the Chrysler

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
			Town & Country LX and Dodge Grand Caravan SCT beginning in 2005, the midgate (a door that folds down to extend cargo space) for the GM Chevrolet Avalanche beginning in 2001, the motor covers for marine applications by SeaRay (Marine division of Brunswick Corp), and the pickup truck box and tailgate assembly for the 2001 to 2004 GM Chevrolet Silverado. Boeing's 787 "Dreamliner" uses SRIM composites for structural parts, increasing fuel efficiency by 3 percent. Overall fuel savings is 20 percent compared with the 747. First commercial flight is scheduled for 2008
Bosch (formerly Allied Signal)	95-07-0020	Developed a synergy between design and casting processes that resulted in the following accomplishments: elimination of porosity problem (zero rejects for porosity); reduction from one large and three small defects per part to two small defects per part; acceleration of research by two years ahead of where it otherwise would have been through parallel research efforts; and reduction of defects in a specific type of valve body design by up to 85 percent	The technical challenges of this project were too numerous and difficult to overcome. As a result, AlliedSignal created no new products for brakes using the technology developed under the ATP-funded project. The Top Die Casting Company produced some components using the new processes, such as air brake valves and brackets. Stahl Specialty Company used one step of the aluminum manufacturing process to assist in aluminum filtration. That process had a small impact on several of the company's product lines
BP Amoco	93-01-0234	Developed a process using silver nitrate as a facilitating agent in high-efficiency contactors and had developed a promising new complexing agent that would potentially cost less than silver nitrate when used for facilitated transport	Although the process was technically sound, the company was experiencing costly operating problems. Amoco was unable to demonstrate the economic feasibility of using this new technology for olefin-paraffin separations and therefore did not commercialize the technology
Catalytica Energy Systems (formerly Catalytica, Inc.)	94-01-0190	Developed catalysts with enhanced activity and selectivity for use in the chemical and petroleum-refining industries	Developed a Multiple Stream Mixer/Reactor (MMR) which may prove to be a very valuable tool for the emerging nanotechnology sector, producing nanoparticles for many industries. The company expected to sell its first major

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
			production MMR system in 2005 or 2006
Crucible Materials Corporation, Crucible Companction Metals Division	94-01-0287	Developed alloys with high levels of nitrogen that demonstrated the potential to produce high-strength, corrosion-resistant stainless steel	Commercialized high-nitrogen alloys that could improve the performance of stainless steel (SS100)
GM Thermoplastic Engineering Design (Engineering Design with Thermoplastics)	92-01-0040	Developed models and generated data for "virtual design" in order to improve the design and development of thermoplastic automotive parts. The project team linked two commercial software tools, Moldflow (formerly C-MOLD) and ABAQUS, with new failure theories for plastics in order to integrate mold design with parts performance	Commercialized virtual design tools that have shortened development time and have improved the performance of thermoplastic parts, which has benefited many manufacturers (for example, Delphi's thermoplastic radiator tank and many other parts; GM's injection-molded plastic intake manifold and other engine components; GE Plastics' improved raw material, which is used in business equipment, optical media, and telecommunications devices). The project resulted in the International Organization for Standardization (ISO) issuing a new standard (ISO 94-5)
Honeywell (formerly Allied Signal)	93-01-0104	Developed powder injection molding used in the ceramic industry for chinaware, spark plugs, oxygen sensor components, and oxygen sensor insulators	Commercialized ceramic powder injection molding technology that is being used in chinaware, spark plugs, oxygen sensors, ball bearings, manufacturing components (for example, stamping punches and guide rollers), engine and machine components (for example, nozzles, seals, shafts, valves, and heating units), and bio ceramics (for example, artificial bones for human replacement surgery)
Honeywell (formerly Allied Signal)	95-07-0003	Developed "aqueous injection molding" (AIM) process improvements for ceramic splitter vanes	Commercialized ceramic splitter vanes in 1998. They had plans to commercialize other small, complex, high-volume parts like blades and nozzles

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
IBM T.J. Watson Research Center	93-01-0149	Developed a conducting polymer of acid-doped polyaniline (PANI) with thermal stability greater than 250 degrees C from 150 degrees C, increasing processability and solubility, and increasing conductivity by 2.5 orders of magnitude	Commercialized a water-soluble version of PANI that was licensed to Monsanto Chemical Corporation in 1997, and IBM is pursuing further licensing opportunities
PCC Structurals	95-07-0011	Developed a casting technology that combines the superalloy processing capabilities of investment casting with the economic advantages of sand casting and achieves part sizes sufficient to produce exhaust frames for industrial gas turbine engines	PCC did not commercialize the new casting technology. They did develop prototypes of a new casting technology that will allow manufacturers to produces large structural superalloy components for industrial equipment industries, such as the Industrial Gas Turbine industry
Praxair, Inc.	94-01-0111	Developed new materials highly selective for oxygen, including IC-2, IA-1, IA-2, and IA-3, which have the potential of meeting all characteristics of a successful material with further development	The O2-selective materials developed during this ATP-funded project have not been commercialized. However, as of 2003, Praxair has continued work on their development through a project with the Department of Energy with hopes to commercialize in the future
The Dow Chemical Company	95-05-0002	Developed a direct, economical, single-product oxidation process incorporating a silver-based catalyst for conversion of propylene to propylene oxide	Dow researchers expect that they might complete a process to develop a direct oxidation propylene sometime between 2006 and 2014. A successful process will reduce energy consumption, cost, and waste in the manufacturing of many types of plastics, lubricants, coatings, surfactants (detergents), and composite materials
Wyman-Gordon	95-07-0026	Developed an incremental forging process to produce near-net shape forgings for industrial gas turbines using a lower-tonnage press than was previously possible	Wyman-Gordon has incorporated the incremental forging process into its business operations

Table A-2. Biotechnology

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
Aphios Corporation	95-01-0263	Developed a knowledge base and technology platform to tap into the pharmaceutically, industrially, and environmentally valuable chemical diversity that remains unexplored in enormous numbers of marine microorganisms	An anti-plaque solution for toothpaste or mouthwash, which is being optimized through chemistry, is the nearest product to commercialization. Novel therapeutics for multiple-disease-resistant (MDR) bacteria, influenza, HIV/AIDS, cancer, and smallpox are also undergoing trials in preclinical drug discovery and development
Cengent Therapeutics Inc. (formerly Moldyn Inc.)	94-01-0137	Developed a software that adapts a technology developed in the aerospace industry to simulations of biological molecule and drug interactions, for the purpose of qualifying drug research candidates in a more timely and efficient manner than by using trial-and-error techniques	The MD simulation software was briefly commercialized through a license to Molecular Simulations Incorporated, but failed to gain sufficient sales and was discontinued. However, Moldyn's software was incorporated with Harvard's Chemistry at Harvard Macromolecular Mechanics (CHARMM) molecular modeling tool through a licensing agreement between Moldyn and Harvard University
Dow AgroSciences LLC (formerly Mycogen Corporation)	95-01-0148	The company made strides in genetic research and demonstrated for the first time that yeast is transformable. They demonstrated that squalene could be hyper-produced in oleaginous yeast; and they gained a broader understanding of the metabolic pathways for isoprene formation in yeast	No commercialization occurred because the oleaginous yeast fermentation project was ended due to technical barriers with enzyme manipulation
DuPont Qualicon (formerly DuPont FQMS Group)	94-05-0033	Developed a functioning automated, rapid DNA diagnostic prototype system that reduced analysis time from 3 hours to 30 minutes. The system can determine the presence or absence of specific microbial contamination as a means of quality control in the food industry. However, DNA pattern results from sample testing were somewhat inconsistent and needed further development	Additional steps were required in sample preparation that negated the time saved in analysis. DuPont Qualicon ended the research into this automated system in 1998, but the company did apply some of the automation knowledge gained in this project to its ongoing alternate food-borne pathogen-testing technologies

Genosensor Consortium (c/o Houston Advanced Research Center)	92-01-0044	Developed a technology for automated DNA sequence analysis	Provided sample analysis and database services for genotyping and gene expression research to organizations such as the Schering Plough Research Institute. In 1999, consortium member Sigma Genosys began to sell Panorama Gene Arrays, which profile gene expression in human cytokines, B. subtilis, and E. coli. In 2003, Sigma Genosys sold human cancer oligoarrays. In 2003, consortium member Beckman Coulter started to commercialize arrays
Incyte Corporation (formerly Combion, Inc.)	94-05-0019	Developed a method akin to ink-jet printing for synthesizing large arrays of specific DNA fragments suitable for medical diagnosis, microbial detection and DNA sequencing, and for creating supplies of detachable oligonucleotides for subsequent use	Microarray expertise and knowledge gained in this project formed the foundation for Incyte's highly successful bioinformatics business, which operated from 1999 to 2001 (selling subscriptions to databases of DNA information). Although Incyte put the specific chem-jet microarray manufacturing techniques developed in this project on hold from approximately 1998 to 2004, the company licensed the technology to Agilent in 2001. As of 2004, Agilent was about to commercialize the ATP-funded technology in conjunction with their numerous other patented chem-jet technologies
JDS Uniphase (formerly The Uniphase Corporation)	94-05-0004	Although the attempt to develop a compact, efficient, and cheaper source of blue light for fluorescence-based diagnostic instruments and techniques for physicians and biomedical researchers was unsuccessful, the project led to the development of two unanticipated products	Commercialized the Blue Laser Module, a stripped-down, inexpensive blue laser for tabletop applications within the biotechnology industry, that reached the market in 1999 and has achieved sales as high as $500,000 per year. They also sold the MicroBlue SLM, a specialized, low-noise blue laser for digital photo-finishing, that was first marketed in 2000 and generated $1 million in annual sales
Large Scale Biology Corporation (formerly Large Scale Proteomics Corporation)	94-01-0284	Developed the ProGEx product line for protein identification and research. The company also completed the first version of the Human Protein Index by identifying more than 115,000 proteins from 157 medically relevant human tissues	The 2-D gel and ProGEx line of protein analysis tools has been upgraded and improved over the years. Large Scale Biology Corporation (LSBC), which acquired LSPC in 1999, still sells research products and databases created through use of technology flowing from the knowledge acquired during this ATP-funded

			project. The company performs up to one million mass spectrometry analyses of proteins per week
Medical Analysis Systems (formerly NAVIX)	95-08-0017	Developed a two-stage reaction for DNA identification and amplification. The process identifies areas of DNA that correlate with disease	Navix did not commercialize any products from its ATP-funded research. Business issues delayed research long enough for another competitor to beat Navix to the market
Monsanto (formerly Agrecetus)	94-01-0074	Developed a prototype plant with elevated levels of poly-3-hydroxybuteric acid (PHB). Although the PHB concentration was not high enough for commercialization, simply raising the PHB level at all represented a technical achievement	Due to the difficulty in attaining high enough PHB levels in the cotton fibers without "crowding out" the fibers' favorable traits, no commercialization efforts resulted from this ATP-funded research.
Orchid BioSciences (formerly Molecular Tool, Inc. Alpha Center)	94-05-0034	Developed techniques for micromachining and for handling fluids on a microscopic scale to make a simple, compact DNA typing instrument	Developed the SNPstream Ultra High Through-Put (UHT), automated array-based genotyping tool. Entered the market through Orchid BioSciences in 2001. Product, intellectual property, and research and development were sold to Beckman Coulter in December 2002. As of 2004, Beckman continues to develop and enhance the system, marketing to research and clinical laboratories. Orchid BioSciences provides genetic analyses using SNPstream UHT on a fee-for-service basis (for biotech companies, pharmaceutical companies, and criminal justice agencies). Orchid's facility was providing up to 1 million SNP scores per day by the end of 2000 on a fee-for-service basis
Valentis, Inc. (formerly Progenitor, Inc.; a subsidiary of Internueron Pharmaceuticals)	94-01-0301	Developed an understanding of how the Del-1 gene regulates angiogenesis and can be used to treat ischemia	In 2003, the company completed a Phase I clinical trial and initiated a Phase II clinical trial for Del-1 angiogenesis product for the treatment of peripheral arterial disease

Table A-3. Electronics, Computer Hardware, or Communications

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
eMagin Corporation (formerly FED Corporation)	93-01-0154	Developed manufacturing techniques for large-scale, flat-panel displays based on arrays of field emitters, a sort of "flat CRT"	Commercialized two microdisplays, SVGA 3D and SVGA+ rev2. The microdisplays are integrated into hundreds of medical, commercial, and military applications. For example, firefighters see through thick smoke by looking through a thermal-imaging camera lens to find victims, even under a blanket. They can also use the lens to find the source of a fire quickly and put it out. Researchers and doctors are using the display to enhance vision for magnetic resonance imaging (MRI), endoscopic surgery, and eye surgery
INSIC (formerly NSIC) - Short Wavelength	90-01-0231	Developed optical recording standards to improve upon traditional magnetic recording	NSIC members did not commercialize optical recording devices because remaining technical obstacles would have required significant further development of the frequency-doubling technology; and by the end of the project, competition was looming from direct-lasing green and blue diode lasers
Kopin Corporation	94-01-0304	Developed liquid crystal projection display technology capable of producing high-quality, high-resolution images for high-definition TV	Commercialized the CyberDisplay 320 Monochrome, the CyberDisplay 320 Color, the CyberDisplay 640 Color, the CyberDisplay 1280 Monochrome 60" diagonal projection HDTV, the CyberDisplay 1280 Monochrome 55" diagonal projection HDTV, the CyberDisplay 1280 Monochrome 46" diagonal projection HDTV, and CyberDisplay 1280 Monochrome 43" diagonal projection HDTV
Planar Systems, Inc. (American Display Consortium)	93-01-0054	Developed a group of patterning technologies necessary to manufacture color flat-panel displays, including large-area photo exposure tools, large-area masks, wet and dry etching tools, printing tools, panel alignment methods and a final inspection tool	Subcontractor, Photronics (now Infinite Graphics, Inc. [IGI]), commercialized customized large-area photo masks for use in high-end printer circuits, calibration plates, x-ray systems, and flat-panel displays. Photronics also developed two processes: mask cleaning & laser pattern generator

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
			Subcontractor, Plasma-Therm successfully commercialized dry etching processes in its Clusterlock 7000 for 6-inch wafers. The company was sold to a Swiss company, Oerlikon-Buehrle in 1999. Planar used the Plasma-Therm etcher to produce AMEL microdisplays until 2002. Subcontractor, YieldUp (now FSI) developed drying tools for wet-etched substrates. This is now used for flat-panel displays and primarily computer chip manufacturing. Also used in hard disk drive cleaning and photomask cleaning. Currently, the ATP-funded component is key in seven larger processing systems:ZETA Spray Cleaning System, ANTARES CX Advanced Cleaning System, EXCALIBUR Vapor HF Etching System, MERCURY Spray Cleaning System, YieldUP 4000 Immersion Etch System, YieldUP 2000 Rinse Dry Module, and YieldUP 2100 STG Rinse Dry Integration Module
SDL, Inc. and Xerox Corporation	91-01-0176	Demonstrated the first integration of multiple-wavelength laser diodes on a single semiconductor device. In the course of this work, the team established several intermediary technologies and accomplished important research in the field of gallium nitride (GaN)-based blue laser diodes. Demonstrated technologies include two alternative methods for monolithic integrations of red, infrared, and blue emitters; red laser diodes with powers of up to 120 mW single mode; lasers in the 700- to 755-nm range; green and blue lasers with frequency doubling; and the lasing of blue GaN diodes at room temperature	After the ATP-funded project, SDL commercialized several laser products that were based on technologies developed in the course of the project: a single-mode laser using facet passivation technology; a single-mode laser for PDT applications; a dual-spot single-mode laser for data storage, printing, displays, and alignment; a multi-mode laser; fiber coupled laser bars for solid state laser pumps, medical systems and displays; and a DBR laser for frequency doubling, interferometry, atomic clocks, and spectroscopy
Superconductor Technologies Inc. (formerly Conductus)	91-01-0134	Developed a prototype superconducting DSP switch	Commercialization of the technology developed and tested during this ATP-funded project was not pursued due to a lack of interest in the technology on the

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
			part of the semiconductor and communications industries
Texas Instruments Inc.	94-01-0221	Developed a special insulating material, known as aerogel, to be integrated adjacent to on-chip interconnects in order to overcome problems with interconnect delay as a result of the continuing trend toward miniaturization. Texas Instruments and NanoPore developed the world's first fully automated manufacturing process to dry an aerogel quickly	The company overcame impediments to aerogel processing early in the project, but in 1997, an industry competitor announced that it would begin using copper interconnect wiring in future integrated circuit designs. Texas Instruments then shifted focus away from aerogels for aluminum and began to develop copper interconnects. Before shifting focus, however, Texas Instruments transferred its aluminum circuit aerogel knowledge to NanoPore, which later sold the rights to continue development of the product to Honeywell. Honeywell's development efforts resulted in a product that they marketed briefly in 2002 to companies for use in manufacturing semiconductors. However, Honeywell withdrew the product in 2004 after it did not fulfill its potential as a new and innovative insulator

Table A-4. Information Technology

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
Accenture (formerly Andersen Consulting Center for Strategic Research)	94-06-0012	Developed a prototype technology for reusable software components based on software architecture considerations, including formal languages to express semantics, a graphical user interface programming environment, automated techniques for assuring that the separate components are logically compatible and properly combined, and automated systems to generate executable systems	No product was commercialized as the technology focus of the industry changed shortly after the project concluded
Cerner Corporation	94-04-0008	Developed information tools to automate, validate and distribute clinical practice guidelines for mass use	Used general concepts from the ATP-funded project to execute guidelines in its Cerner Millennium product. With Cerner Millennium, clinicians are electronically alerted about potential patient safety and regulatory issues through evidence-based medical information
Cerner Corporation (formerly DataMedic - Clinical Information Advantages, Inc.)	94-04-0038	Developed a knowledge-base-driven automated coding system in the form of a software component, CHARTnote which uses MEDencode, a technology that automatically gathers, codifies, and records specific detailed information about a patient	The software is currently incorporated into and sold with approximately 7 CHARTstation products, manufactured by VitalWorks. It is also sold separately and with other products. Products include GIstation, EMstation, EYEstation, RADstation, and other areas including internal medicine and family practice, renal dialysis, and rehabilitative medicine
InStream	94-04-0018	Developed the first behavioral healthcare (BHC) Web portal for claims processing	The software product was briefly commercialized in 1998, but was quickly overtaken by competing products after a lack of funding prevented InStream from providing the necessary upgrades and market penetration to reach positive cash flow
Lucent Technologies (formerly AT&T Bell Laboratories)	94-06-0011	Developed and successfully demonstrated their software (Symphony) to develop an easy-to-use, graphics-user interface (GUI) software assembly system for nonprogrammers that handles the complexity of building reliable,	No commercialization resulted from this project because of AT&T's corporate restructuring in 1996. Lucent decided to discontinue its development of the reusable software component product

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
		custom-designed software by using libraries of reusable, software components	
SciComp, Inc.	94-06-0003	Developed a component software and a software synthesis technology for creating mathematical models in the field of scientific computing	As of 2004, SciComp offered three software tools in the SciFinance solution that incorporate the ATP-funded software synthesis technology; SciFinance also includes two additional products that enhance SciPDE and SciMC. SciComp experienced greater demand for these products as the market
Titan Systems (formerly Intermetrics)	94-04-0040	Developed a script language and a related suite of software tools to facilitate the process of developing customized home healthcare workstations for homebound or limited-mobility, chronically ill patients	A product was not commercialized. The intellectual property was acquired by HealthVision, which chose not to further develop it
Xerox Palo Alto Research Center	94-06-0036	Developed a new programming technique called aspect-oriented programming (AOP). They also developed two prototype applications of specialized computer languages	AspectJ, an open-source language that extends Java, is now used in a significant percentage of IBM's new products and is an open-source platform. PARC transferred AspectJ to the open-source eclipse.org project in December 2002

Table A-5. Manufacturing

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
Abrasive Technology Aerospace, Inc.	95-02-0053	Developed an integrated CAD/CAM approach to applying superabrasive coatings to complex surfaces of electroplated superabrasive grinding wheels	In 2000, Abrasive Technology began to market and sell electroplated superabrasive grinding wheels using the CAD/CAM technology it developed during the ATP-funded project, and still continues to do so. The company has used the new technology to produce grinding wheels for a variety of industries, including automotive and aerospace
Cincinnati Lamb, UNOVA (Lamb Technicon)	95-02-0019	Developed an experimental prototype of a flexible line boring station with intelligent tooling and controls	The BOA technology was not commercialized because auto manufacturers found less expensive machine tools to meet their specifications
General Electric Corporation R&D	95-07-0018	Developed an intelligent process for applying thermal barrier coatings to critical components in turbine engines for power plants in order to raise firing temperatures and increase fuel efficiency	GE successfully produced an improved gas turbine engine for its new H-System combined-cycle power plant, which can achieve 60-percent energy efficiency. The high-performance thermal barrier coatings developed in part using technology from this project were essential to the design of this model. GE also applied the knowledge to upgrade existing F-System plants, which achieved 56-percent efficiency. Other companies have used the process on marine aircraft and heavy diesel engines, as well as other applications
IBM Corporation	94-03-0012	Developed an automated tool kit that could be used by vendors to develop, maintain, and join interoperating families of enterprise resource planning (ERP) and manufacturing execution system (MES) applications	IBM did not commercialize its new automated tool kit. Instead, it commercialized a service based on its new Framework for Adaptive Interoperability of Manufacturing Enterprises (FAIME) technology, enterprise application integration (EAI) services
Montronix	95-02-0020	Developed a diagnostic system that can monitor the vital signs of machining operations in real time to provide a trouble-shooting aid for process engineers who are increasingly challenged to efficiently machine smaller	The developed monitoring system later evolved into a standard Montronix product line called Spectra. A key accomplishment of this project was providing free Internet-based simulated machine-tool modeling

A. Awardee Name	B. Project Number	C. Technology Developed	D. Products or Processes Commercialized or Expected to be Commercialized Soon
		volumes of a wider variety of parts	(http://mtamri.me.uiuc.edu/testbeds/testbed.intro.html). The web-based simulation is still in use by government, research and industry
United Technologies Research Center	95-06-0011	Developed a prototype handheld device to detect refrigerant leaks during manufacture of components containing refrigerant	No commercialization occurred. All three companies cited cost of development, lack of funding, competition, and uncertain market demand as contributing factors to discontinuing research into this technology. The markets for the laser emitter for the handheld unit were also limited
York International	95-06-0004	Developed a prototype heat exchanger that was 25 percent smaller and had the same heat transfer capability as the standard size. Furthermore, York developed a method and a tool that they still use in their ongoing research and development. They also demonstrated that oval-tube geometry is 10 percent more efficient for heat transfer than round tubes	Using the methods developed during this project, York developed a new commercialized plate fin, called HiQ. York uses the fin in its ECO2 rooftop heating/cooling units. Its proprietary enhancements yield approximately twice the heat transfer when compared to a standard fin. Due to the prohibitive manufacturing capital cost, York has postponed commercializing oval-tube coil technology

APPENDIX B

Reasons for Terminating ATP Projects

At the end of an ATP competition, projects are selected for award and the winners are announced. Most of these projects proceed through their multi-year research plans to completion. Some are not carried through to completion for a variety of reasons. These projects are collectively called "terminated projects."

Between 1990 and September 2004, there were 768 ATP awards issued, of which 84[22] projects ended before completion. Below is a percentage distribution by category of the reasons for termination.

Change in goals
- 54 percent ended because of changes in the strategic goals of the companies, changes in the business climate or markets, changes in company ownership, or other business-related facts.

Lack of technical progress
- 12 percent ended because of lack of technical progress, which sometimes occurs at go/no-go decision points recommended by the participant(s).

Project no longer meets ATP criteria
- 11 percent ended because changes in scope, membership, performance, or other factors meant that the project no longer met ATP's technical and/or economic criteria.

Lack of agreement among joint venture members
- 2 percent ended because the joint venture members could not reach an agreement on some issues.

Financial distress
- 11 percent ended due to the financial distress of a key participant.

Early success
- 5 percent ended due to early success of the project!

Although projects may end early, it is not necessarily an indication of total failure. Projects that ended early produced important knowledge gains; involved integrated planning for research, development, and business activities that may have some benefit to participating companies; and entailed substantive cross-disciplinary contact among scientists and other researchers, cross-talk among technical and business staff, and negotiations among executives at different companies.

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[22] Included in this figure are four projects that were cancelled before the project began, comprising approximately 5 percent of the total.

These characteristics still benefit the economy by stretching the thinking and horizons of participants in the process. Companies may learn about new opportunities and apply integrated planning of research and business activities to other projects. In summary, terminated projects may have some positive impact even though they incur costs.

APPENDIX C

Composite Performance Rating System (CPRS) Star Ratings—First 150 Completed Projects

Project Number	Project Identifier (Title/Lead Organization)	Data Set	Overall Project Success
91-01-0243	Aastrom Biosciences, Inc.	1st 50	****
91-01-0146	American Superconductor Corp.	1st 50	****
94-02-0027	Automotive Composites Consortium (a Partnership of DaimlerChrysler [formerly Chrysler], Ford and General Motors)	3rd 50	****
94-04-0038	Cerner Corporation (formerly DataMedic - Clinical Information Advantages, Inc.)	3rd 50	****
96-01-0263	ColorLink, Inc.	2nd 50	****
91-01-0256	Cree Research, Inc.	1st 50	****
91-01-0184	Engineering Animation, Inc.	1st 50	****
93-01-0085	Integra LifeSciences	1st 50	****
94-01-0304	Kopin Corporation	3rd 50	****
94-01-0284	Large Scale Biology Corporation (formerly Large Scale Proteomics Corporation)	3rd 50	****
91-01-0041	Nanophase Technologies Corporation	2nd 50	****
90-01-0154	National center for Manufacturing Sciences (NCMS)	1st 50	****
94-05-0034	Orchid BioSciences (formerly Molecular Tool, Inc. Alpha Center)	3rd 50	****
94-06-0003	SciComp, Inc.	3rd 50	****
91-01-0176	SDL, Inc. and Xerox Corporation	3rd 50	****
94-05-0012	Third Wave Technologies, Inc.	2nd 50	****
92-01-0133	Tissue Engineering, Inc.	1st 50	****
94-06-0024	Torrent Systems, Inc. (formerly Applied Parallel Technologies, Inc.)	1st 50	****

Project Number	Project Identifier (Title/Lead Organization)	Data Set	Overall Project Success
94-06-0036	Xerox Palo Alto Research Center	3rd 50	****
91-01-0112	X-Ray Optical Systems (XOS), Inc.	2nd 50	****
95-05-0034	ABB Lummus Global, Inc. (formerly ABB Lummus Crest)	3rd 50	***
95-01-0131	Advanced Refractory Tech	3rd 50	***
93-01-0113	Amersham Pharmacia Biotech (formerly U.S. Biochemical Corporation)	1st 50	***
91-01-0177	Auto Body Consortium	1st 50	***
94-01-0115	Calimetrics, Inc.	1st 50	***
93-01-0055	Caterpillar Corporation	2nd 50	***
95-01-0022	Corning Tropel (formerly Tropel Corporation)	2nd 50	***
92-01-0136	Cynosure, Inc.	1st 50	***
95-02-0055	Dana Corporation	2nd 50	***
92-01-0115	Diamond Semiconductor Group, LLC	1st 50	***
98-02-0034	Digital Optics Corporation	2nd 50	***
94-01-0402	Displaytech, Inc.	2nd 50	***
90-01-0064	E.I. Du Pont de Nemours & Company	1st 50	***
94-02-0025	Ebert Composites Corporation	2nd 50	***
95-11-0012	EDO Specialty Plastics (formerly Specialty Plastics Inc.)	2nd 50	***
93-01-0154	eMagin Corporation (formerly FED Corporation)	3rd 50	***
91-01-0178	Ford Motor Company	2nd 50	***
95-07-0018	General Electric Corporation R&D	3rd 50	***
92-01-0044	Genosensor Consortium (c/o Houston Advanced Research Center)	3rd 50	***
92-01-0040	GM Thermoplastic Engineering Design (Engineering Design with Thermoplastics)	3rd 50	***

Project Number	Project Identifier (Title/Lead Organization)	Data Set	Overall Project Success
92-01-0116	Honeywell (formerly Allied Signal Inc.)	2nd 50	***
95-09-0052	Hynomics (formerly Hybrithms Corporations, formerly Sagent Corporation)	2nd 50	***
94-05-0018	Hyseq, Inc.	2nd 50	***
93-01-0149	IBM T.J. Watson Research Center	3rd 50	***
92-01-0017	Illinois Superconductor Corporation	1st 50	***
94-05-0019	Incyte Corporation (formerly Combion, Inc.)	3rd 50	***
91-01-0016	Information Storage Industry Consortium (INSIC, formerly NSIC)	2nd 50	***
91-01-0262	Kopin Corporation	1st 50	***
93-01-0101	Kurzweil Applied Intelligence, Inc	2nd 50	***
93-01-0183	MicroFab Technologies, Inc.	2nd 50	***
91-01-0224	Molecular Simulations, Inc. (formerly Biosym Technologies, Inc.)	1st 50	***
96-01-0172	Nanogen, Inc.	2nd 50	***
90-01-0166	Nonvolatile Electronics, Inc.	1st 50	***
93-01-0071	Perceptron, Inc.	1st 50	***
93-01-0205	Physical Optics Corporation (POC)	2nd 50	***
94-04-0024	PPD Informatics (formerly Belmont Research, Inc.)	2nd 50	***
92-01-0123	Sage and 3M Corporation	1st 50	***
94-02-0010	Strongwell Corporation	2nd 50	***
94-04-0046	Surgency (formerly Benchmarking Partners)	2nd 50	***
95-05-0002	The Dow Chemical Company	3rd 50	***
97-01-0087	TopicalNet (formerly Continuum Software, Inc.)	2nd 50	***
93-01-0124	Vitesse Semiconductor Corporation	1st 50	***

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94-04-0027	3M Company, Health Information Systems	2nd 50	**
95-02-0053	Abrasive Technology Aerospace, Inc.	3rd 50	**
91-01-0187	AlliedSignal, Inc.	1st 50	**
90-01-0060	American Display Consortium	1st 50	**
95-01-0263	Aphios Corporation	3rd 50	**
91-01-0142	AstroPower, Inc.	1st 50	**
93-01-0250	BioTraces, Inc.	1st 50	**
95-07-0020	Bosch (formerly Allied Signal)	3rd 50	**
93-01-0234	BP Amoco	3rd 50	**
94-01-0190	Catalytica Energy Systems (formerly Catalytica, Inc.)	3rd 50	**
94-01-0137	Cengent Therapeutics Inc. (formerly Moldyn Inc.)	3rd 50	**
95-02-0019	Cincinnati Lamb, UNOVA (Lamb Technicon)	3rd 50	**
90-01-0210	Communication Intelligence Corporation	1st 50	**
93-01-0211	Communication Intelligence Corporation	1st 50	**
94-01-0287	Crucible Materials Corporation, Crucible Companction Metals Division	3rd 50	**
93-01-0091	Elsicon (formerly Alliant Techsystems, Inc.)	2nd 50	**
92-01-0022	FSI International, Inc.	1st 50	**
92-01-0074	Geltech Incorporated	1st 50	**
94-01-0147	Genzyme Corporation (formerly GelTex Pharmaceuticals, Inc.)	2nd 50	**
91-01-0034	HelpMate Robotics, Inc. (formerly Transitions Research Corporation)	1st 50	**
93-01-0104	Honeywell (formerly Allied Signal)	3rd 50	**
95-07-0003	Honeywell (formerly Allied Signal)	3rd 50	**

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94-05-0004	JDS Uniphase (formerly The Uniphase Corporation)	3rd 50	**
94-01-0133	Laser Power Corporation	2nd 50	**
90-01-0212	Light Age, Inc.	1st 50	**
90-01-0121	Lucent Technologies Inc.	1st 50	**
93-01-0191	M&M Precision Systems Corporation	2nd 50	**
92-01-0053	Mathematical Technologies Inc.	1st 50	**
91-01-0088	Michigan Molecular Institute	1st 50	**
93-01-0027	Micron Optics, Inc.	2nd 50	**
95-02-0020	Montronix	3rd 50	**
95-08-0009	Nanogen, Inc.	2nd 50	**
94-01-0357	Norton Diamond Film	2nd 50	**
93-01-0054	Planar Systems, Inc. (American Display Consortium)	3rd 50	**
94-06-0026	Reasoning Systems, Inc.	2nd 50	**
90-01-0232	Saginaw Machine Systems, Inc.	1st 50	**
91-01-0263	Spire Corporation	1st 50	**
94-01-0221	Texas Instruments Inc.	3rd 50	**
94-06-0034	TopicalNet, Inc. (formerly Continuum Software, Inc.)	2nd 50	**
94-01-0063	Union Switch and Signal, Inc.	1st 50	**
94-01-0301	Valentis, Inc. (formerly Progenitor, Inc.; a subsidiary of Interneuron Pharmaceuticals)	3rd 50	**
91-01-0261	Westinghouse Plasma Corp.	1st 50	**
93-01-0041	Air Products and Chemicals, Inc.	3rd 50	*
94-04-0017	American Healthware Systems	2nd 50	*

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94-02-0040	Budd Company, Design Center	2nd 50	*
92-01-0132	GE Corporate Research and Development	2nd 50	*
91-01-0069	Honeywell, Inc., Technology Center	2nd 50	*
94-03-0012	IBM Corporation	3rd 50	*
92-01-0034	Ingersoll Milling Machine Company	2nd 50	*
90-01-0231	INSIC (formerly NSIC) - Short Wavelength	3rd 50	*
94-04-0037	KOOP Foundation, Inc.	2nd 50	*
95-10-0067	KOOP Foundation, Inc.	2nd 50	*
91-01-0258	Microelectronics Center of NC	1st 50	*
95-02-0005	Perceptron (formerly Autospect, Inc.)	2nd 50	*
93-01-0045	Philips Laboratories	2nd 50	*
94-01-0111	Praxair, Inc.	3rd 50	*
91-01-0267	PreAmp Consortium	1st 50	*
91-01-0134	Superconductor Technologies Inc (formerly Conductus)	3rd 50	*
93-01-0109	Thomas Electronics, Inc.	1st 50	*
95-06-0011	United Technologies Research Center	3rd 50	*
95-07-0026	Wyman-Gordon	3rd 50	*
95-06-0004	York International	3rd 50	*
94-06-0012	Accenture (formerly Andersen Consulting Center for Strategic Research)	3rd 50	-
94-04-0025	Accenture (formerly Andersen Consulting)	2nd 50	-
92-01-0055	Accuwave Corporation	1st 50	-
91-01-0135	Aphios Corporation	1st 50	-

Project Number	Project Identifier (Title/Lead Organization)	Data Set	Overall Project Success
91-01-0025	Armstrong World Industries, Inc.	1st 50	-
92-01-0007	Calmac Manufacturing Corporation	2nd 50	-
94-04-0008	Cerner Corporation	3rd 50	-
95-01-0148	Dow AgroSciences (Mycogen Corporation)	3rd 50	-
94-05-0033	Dupont Qualicon (formerly Dupont FQMS Group)	3rd 50	-
92-01-0109	Eagle-Picher Research Laboratory	2nd 50	-
92-01-0122	ETOM Technologies, Inc. (formerly Optex Communications, Inc.)	1st 50	-
95-05-0031	General Electric Company	2nd 50	-
90-01-0126	Hampshire Instruments, Inc.	1st 50	-
91-01-0017	IBM Corporation	1st 50	-
92-01-0103	IBM Corporation	1st 50	-
94-04-0018	InStream	3rd 50	-
94-06-0011	Lucent Technologies (formerly AT&T Bell Laboratories)	3rd 50	-
91-01-0057	MediaBin (formerly Iterated Systems Incorporated)	2nd 50	-
95-08-0017	Medical Analysis Systems (formerly NAVIX)	3rd 50	-
94-01-0074	Monsanto(formerly Agrecetus)	3rd 50	-
92-01-0124	NetOptix Corporation (formerly Galileo Corporation)	1st 50	-
95-07-0011	PCC Structurals	3rd 50	-
95-07-0006	Praxair Surface Technologies, Inc.	2nd 50	-
92-01-0035	Sheffield Automation (formerly Giddings & Lewis)	2nd 50	-
91-01-0071	Thermo Trilogy Corporation	1st 50	-
94-04-0040	Titan Systems (formerly Intermetrics)	3rd 50	-