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ACCELERATION OF TECHNOLOGY DEVELOPMENT BY THE ADVANCED TECHNOLOGY PROGRAM: The Experience of 28 Projects Funded in 1991

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EXECUTIVE SUMMARY

The Advanced Technology Program (ATP) is a unique partnership in which the Federal government and private industry jointly fund research and development projects that have high technical risk and commensurately large potential for creating broad-based benefits for the United States. The ATP was created by the Technology Competitiveness Act of 1988, amended by the American Technology Preeminence Act of 1991 (P.L. 100-418 and P.L. 102-245). Industry conceives and proposes research projects to the ATP. The ATP evaluates the proposed projects for their potential to add to the scientific knowledge base and to contribute to the nation's economy, and provides multi-year funding to those projects that score high in rigorous competitions. Research awards are made both to industry-led joint ventures and to single companies. If the research projects are successful, the companies are expected to undertake subsequent commercialization activities and to promote the diffusion of the enabling technologies developed into multiple application areas. The ATP focuses on accelerating the development of those technologies which are likely to have benefits extending well beyond the direct award recipients. In economic terminology, it focuses on funding technologies for which the social return is likely to be high and far in excess of the private return on investment.

The ATP acts as a partner rather than a contractor in the research project. In addition to the funding, awardees often receive technical advice from the NIST scientific staff and advice from ATP's technical and business monitors who provide project oversight for the ATP throughout the project life. In addition, proposers receive constructive feedback upfront from ATP's peer review process on their technical and business plans. The ATP emphasizes integrated planning across all aspects of the project by encouraging participants to establish a team that includes people who are involved with the development of the technology – and people who will be responsible for the eventual application of the technology in products or processes that can be commercialized. Although the ATP provides funding only for research, it requires that upfront planning be done for down-stream activities such as marketing, production, and distribution; and encourages that the voice of the customer or end-user be inserted into the process as soon as possible.

The ATP has an evaluation program to ensure that the projects it funds are on track, to determine their short- and longer-run impacts, and to improve the program's effectiveness. The 1993 Government Performance and Results Act (GPRA) requires evaluation of Federal programs, and the ATP has emphasized evaluation from its start in 1990. In support of that effort, the ATP engages the services of a variety of academic and consulting economists, as well as its own staff. This is one such evaluation study.

Since the ATP-funded projects are multi-year research projects and most of the approximately 300 projects the ATP has funded to date were funded only in the last several years, it is premature to attempt to measure empirically the long-term impacts of the program. However, some of the earlier funded projects have recently completed or are nearing completion of their research phase, and it is beginning to be feasible to conduct preliminary assessments of some of the effects.

The study investigated the impact that participation in the Advanced Technology Program (ATP) has had on the applied research cycle time of a group of program participants from 1991 through the spring of 1996. Cycle-time impacts are of keen interest because one of the ATP's legislated mandates is to assist U.S. businesses in creating and applying generic technology for rapid commercialization.

Earlier surveys found that a majority of program participants believed that participation in the ATP had helped them to reduce cycle time and that it was important to do so – but the earlier surveys which addressed a variety of performance metrics did not provide details on why cycle-time reduction is of special importance to the companies; on how participation in ATP helped them to reduce their applied research and technology development cycle time and get to market more quickly; or on whether there were time effects beyond the ATP project.

Structured telephone interviews with the primary investigators of the 28 projects funded by the ATP in 1991 resulted in the following principal findings:

- The sample included 18 single-company projects, led by 13 small for-profit firms, 3 medium or large companies, and 2 non-profits. In addition, the sample included 10 joint ventures, 4 led by non-profits, 3 led by small companies, and 3 led by large companies.

- Twenty-seven (27) or 96% of the 28 company interviewees estimated that participating in ATP had helped their companies to reduce their technology development cycle time anywhere from 30% to 66% with fourteen estimating a 50% reduction (most typically from a projected six-year cycle down to a three-year cycle).

    - These program participants spoke of a stage in the technology development life cycle that is not usually reflected in the literature . . . that is the "capitalization stage," wherein cash infusions are particularly critical to further progress.

    - The interviewees attributed their cycle-time reduction to ATP's requirements for disciplined and integrated project planning and management; achievement of a critical mass of resources through ATP funding; attraction of additional financial support because of ATP's "Halo Effect;" greater project stability because of a long-term and strategic commitment to solving the technical problem; and ATP's emphasis on collaboration.

- Twenty-four (24) or 86% of the 28 interviewees expected the positive impact on cycle time already experienced in the applied-research stage to flow through to later stages in the technology-development cycle (the product development, production, and marketing stages), thereby causing them to enter the marketplace more quickly.

- Fifteen (15) or 54% of the 28 interviewees were able to quantify their "ball-park" estimates of the economic value of reducing cycle time by just one year, and these estimates ranged from one million to several billions of dollars, with a median value of $5.5 million.

- Twenty-four (24) or 86% indicated that participation in ATP resulted in cycle-time improvements that carried over to other technology development projects outside of ATP. They spoke of adapting specific "ATP practices" to related projects; application of methodologies and processes used or developed in the ATP project to the firm as a whole; adoption of a cultural bias favoring speedier processes; and taking advantage of the positioning provided by the enabling technologies developed in their ATP projects to accelerate the development of a whole series of related applications.

  - These findings on carry-over impacts suggest that ATP's positive impacts on participant cycle time may extend beyond the specific project funded, resulting in broader and longer-term benefits to awardees than might have been anticipated.

  - These findings suggest that ATP may be fostering self-perpetuating, institutionalized practices that reduce cycle time.

The economic vitality of a country depends increasingly on the ability of its companies to harness and use technical capabilities rapidly and effectively. Since applied research is a source of new technologies and product innovations, accelerating research cycle time holds potential for accelerating commercialization of research results and, thereby, promoting the economic growth of the United States and enhancing our quality of life.

From the findings of this study, it appears that the ATP is helping to overcome two types of economic efficiency problems related to speed to market:

1. the difficulty of obtaining funding at all to undertake long-run, high-risk, enabling technology development; and

2. the difficulty of implementing coordinated, collaborative R&D management practices needed to speed the conduct of R&D and the commercialization of the resulting technology.

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CHAPTER I
INTRODUCTION: DELINEATING THE STUDY

1.1 About the Advanced Technology Program (ATP)

The Advanced Technology Program (ATP), which is administered by the National Institute of Standards and Technology, an agency of the Department of Commerce, is a unique partnership between government and private industry to accelerate the development of high-risk, generic technologies that promise significant commercial pay-offs and widespread benefits for the economy. The ATP was created in 1988 with the passage of the Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-418), which directed that the National Institute of Standards and Technology (NIST) expand its outreach beyond laboratory research and development to include a rigorously competitive ATP and the Manufacturing Extension Partnership Program.

The ATP provides funds for the early phases of technology development through cooperative research agreements with single businesses or industry-led joint ventures and research consortia. Awards to individual companies may not exceed $2 million and the period of Federal funding may not exceed three years. Projects by joint ventures may run as long as five years, with no limit on the amount of funding . Single companies that receive awards are reimbursed for part or all of the direct costs of their proposed research but must pay for all overhead costs. Joint ventures, which consist of two or more companies, are reimbursed for less than half of their direct and overhead costs; the companies must provide more than 50 percent of the total funding for their project. (Some of these requirements are expected to change for future competitions.)

The goals of the ATP as stated in its enabling legislation are " to assist U.S. business in creating and applying the generic technology and research results to (1) commercialize significant new scientific discoveries and technologies rapidly and (2) refine manufacturing technologies." As restated in the Federal Register on July 14, 1990, the ATP will assist U.S. businesses to improve their competitive position and promote U.S. economic growth by accelerating the development of a variety of pre-competitive generic technologies by means of grants and cooperative agreements.

Through 1996, the ATP had announced 288 awards and committed $989 million for advanced technology development. The participating organizations (the awardees) had committed over $1 billion dollars in matching funds.

1.2 Is ATP Meeting its Mandate to Accelerate the Development and Commercialization of Technology ?

One of ATP's evaluation interests lies in gaining a better understanding of intra-firm impacts of ATP-funded projects. This study contributes to that area by providing a more in-depth look at the impact of ATP on the awardees' applied research cycle times.[1]

The specific purpose of this study was to evaluate the impact that the ATP is having on applied research cycle time of companies participating in the program, with the larger objective of determining if the ATP is successfully meeting its legislated mandate to accelerate the development and the commercialization of technology. The study focuses on applied research cycle time, because high-risk applied research is largely what the ATP funds, and at this early stage of the ATP, that is the period of time most feasible to evaluate.[2] Although there is a large body of literature and an established discipline that focuses on improving production cycle time and even product-development cycle time, this is not the case for applied-research cycle time. The investigation of applied-research cycle time is a relatively new and emerging discipline.

1.3 What is Cycle Time ?

Cycle time, according to Daniel Jordan, is the following:

"Cycle time is the time required to complete a particular process, such as the product development process, from start to finish. Cycle time is distinct from timeliness. It should be viewed from the customer's perspective in that it includes time required for testing, validation,

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[1]Rosalie T. Ruegg, Guidelines for Evaluation of the Advanced Technology Program, (Gaithersburg, Md.: U.S. Department of Commerce, Technology Administration, National Institute of Standards and Technology Report, NISTIR-5896, November 1996).

[2]The ATP does not fund product development; it funds research for the purpose of creating technology that will eventually lead to new and improved products and services. And though the ATP does not fund streams of basic research, it often funds projects that entail research tasks which are rather basic in nature. Although it is an oversimplification to state categorically that ATP funds applied research, that is predominantly what it funds; and hence, for the purpose of this study, that is the term used.

Although the ATP has technology commercialization as a desired downstream outcome of the research it funds – and some awardees are beginning to commercialize their technologies, it is too early to assess directly the ultimate impact of the program on commercialization. Hence, the study's focus on time changes in the applied research cycle of ATP-funded projects is appropriate.

viewed from the customer's perspective in that it includes time required for testing, validation, modifications and rework. Although not all aspects of cycle time may be under an organization's control, it is important to know where the time is spent in order to best identify opportunities for cycle-time reduction."[4]

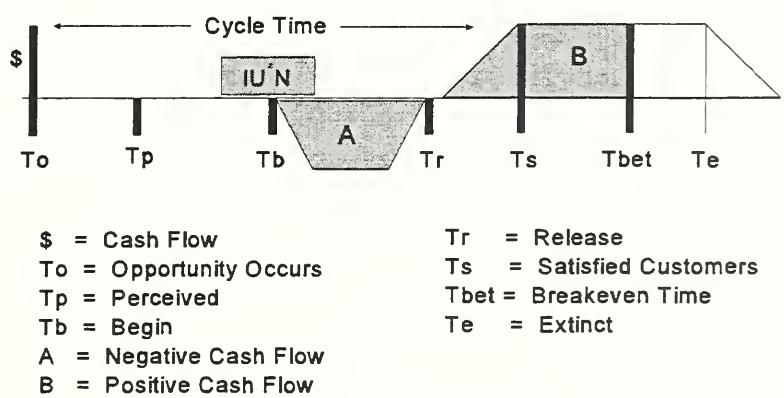
Similarly, Hewlett-Packard defines cycle time as the period of time from the starting point when the opportunity occurs to the point when the customer is satisfied.[5]

Different terms are sometimes used to connote the cycle time concept. These terms include "Time Line," "Cycle Time," "Time to Market," "Speed," and "Slip Rate."

It is relatively easy to define the starting points and ending points for the "downstream" functions of manufacturing, sales, and distribution. It is more difficult to define the starting points and the ending points for the "upstream" functions of applied research and technology development. One can not state with any certainty the starting and ending points for applied research. No matter what one posits, it will be challenged, debated, and discussed.

Hewlett-Packard has instituted a program at the beginning of each new product development cycle called the "Imaginative Understanding of User Needs (IU^2N)." During this time, the organization pulls together its resources and defines the product that will proffer the most competitive response to the opportunity. With reference to Figure 1, the goal is to cut the time between "To" and "Ts" as a strategy to increase return on investment.[6]

Figure 1. Hewlett-Packard Model of Product-Development Cycle Time



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[4]Daniel W. Jordan, "Reducing Project Durations Through Cycle Time Reduction," American Association of Cost Engineers Transactions (AACE), 1993, pp. F.3.1-F.3.4.

[5]Ibid.

[6]Marvin L. Patterson, "Accelerating Innovation: A Dip into the Meme Pool," National Productivity Review, Autumn, 1990, pp. 409-418.

Within the company setting, the main source of cycle-time reduction strategies has traditionally been operations. Typically, cycle-time reduction (CTR) started in manufacturing and then migrated "downstream" to sales and distribution. A question is whether the ATP can start at the applied research end and stimulate time reductions that will propagate forward, from the research cycle through the production and marketing cycles.

1.4 Why Reduce Cycle Time ?

Cycle-time reduction is viewed as increasingly important because it enhances global competitiveness. In the 1970s, Japanese companies adopted a civilian equivalent of maneuver warfare in manufacturing called "cycle-time analysis," and "slaughtered" American competitors. [6]

According to Groves, an Ernst and Young study concluded that Japan is the only country that emphasizes the routine use of both cycle-time analysis and process simplification. About half of the Japanese businesses use these practices more than 90 percent of the time. Fewer than 25 percent of the businesses in the United States, Canada, and Germany use process cycle-time analysis or process simplification to improve their business processes. [7]

In a 1988 Harvard Business Review article titled "Time – The Next Source of Competitive Advantage," George Stalk warned that unless United States companies reduce their new product development and introduction cycles from 36-48 months to 12-18 months, Japanese manufacturers would easily out-innovate and out-perform them.[8] In order to reduce cycle time, Stalk said that domestic firms must learn to develop manufacturing processes and products simultaneously to collapse time and ensure better manufacturability, an approach often referred to as simultaneous or concurrent engineering. [9]

McGrath, Anthony and Shapiro have stated, "If manufacturing and total quality management were viewed as the industrial battlegrounds of the late 1970s and 1980s, product development and cycle-time reduction are the battlegrounds of the 1990s. The advantages that come from reducing time to market and consistently developing better products are so significant that they

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[6]Forbes, Dec. 9, 1991 cited by Dyan Machan, "We're Not Authoritarian Goons," Forbes, Oct. 24, 1994, pp. 246, 248.

[7]Ray Groves, "Leadership in Tomorrow's Global Marketplace," Vital Speeches of the Day, Dec. 15, 1991, p. 144-146.

[8]George Stalk, "Time–The Next Source of Competitive Advantage," Harvard Business Review, July-Aug. 1988, pp.41-51.

[9]Anthony R. Inman, "Time-Based Competition: Challenges for Industrial Purchasing," Industrial Management, Mar. 1992, p. 31.

will shift the competitive balance in favor of companies that can achieve them first. A company that can efficiently introduce more new products, react faster to market and technology changes, and develop superior products will win battles with its competitors. The key to achieving these advantages is improving the product development process and getting to market more quickly. This is why it will become the battleground of the 1990s." [11]

Cycle-time reduction helps a company achieve its goals. As Table 1 shows, high performance companies report faster time-to-market and have more aggressive cycle-time reduction goals than low-performance companies.

Table 1. Cycle-Time Performance of High Versus Low Performance Companies

	Performance Level	Today Months	Goal Months
1. Product Improvement	HI	8.5	5.3
	LO	10.0	5.7
2. Product Line Extension	HI	11.6	7.9
	LO	13.4	9.0
3. New Product Lines	HI	22.8	14.9
	LO	25.8	18.2

Source: Mercer Consulting Company presentation, 1995.

By being first to market, a company favorably impacts its goals as they relate to sales, sales growth, development costs, total costs, profits, market position, market share, customer loyalty, competitors, industry standards and intellectual property rights.[12] In industries dependent on patent protection for high margin, an additional year before the product comes off patent may be extremely valuable. Informal standards, such as the "form factor" or "feel of the product," can also be importantly related to cycle time. Gary Tooker, president of Motorola, pointed out that the form factor for the company's portable hand-held phone established a standard in the industry for "feel" because it was first to market.

Though most of the articles to date on reducing R&D cycle time focus more on the "D" (development) than the "R" (research), there is at least one article that highlights industry's

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[11]Michael E. McGrath, Michael T. Anthony, and Amram R. Shapiro, Product Development: Success Through Product and Cycle-Time Excellence, (Boston: Butterworth-Heinemann, 1992), p. 3.

[12]Ibid., pp. 6-7 and 11.

increasing interest in reducing applied research cycle time. Bob Burkhart's article "Reducing R&D Cycle Time" for the Industrial Research Institute (IRI) states that research at the "fuzzy front end" carries high uncertainty; and successful output cannot be readily scheduled, as with the development phase. Only after identifying the potential causes for uncertainty in the decisions and activities of the research phase might barriers be reduced or removed by applying appropriate solutions; for as knowledge grows, risk recedes and the capacity to advance in a shorter time frame materializes. Bob Burkhart's research for the article came from the IRI's ten-member Management Research Team which used common total quality management (TQM) tools to identify 45 major causes of uncertainty in research in eight different categories, as shown in Table 2. "Customer requirements not defined" and "delays in decision" were the most frequently encountered causes of uncertainty. Forty potential solutions to causes of uncertainty in research were also identified, as shown in Table 3. The solutions outlined by this industry team are consistent with ATP's emphasis on integrated business and technical planning and management.[13]

Table 2. Causes of Uncertainty in Research

Technical Processes (T) 1. Not invented here 2. Science insufficient 3. Effort insufficient 4. Core competency mismatch 5. Skill mismatch 6. Customer interface insufficient 7. Product feature mismatch 8. Technical planning insufficient 9. Technical support insufficient 10. Manufacturing capability insufficient 11. Financially unfeasible 12. Economically unfeasible 13. Timing inappropriate	**Management Style** 1. Management planning insufficient 2. Management effort insufficient 3. Management support insufficient 4. Management review insufficient 5. Business practices restrictive 6. Finances inadequate 7. Reward systems inappropriate 8. External technical interfaces inadequate
Business Processes (B) 1. Risk assessment insufficient 2. Market strategy inadequate 3. Business strategy inadequate 4. Technical strategy inadequate 5. Priorities change 6. Facilities unavailable	**Market** 1. Customer needs definition inadequate 2. Requirements inadequately defined 3. Market intelligence insufficient 4. Sales capability insufficient 5. Distribution capability insufficient 6. Value chain understanding insufficient

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[13]Robert E. Burkhart, "Reducing R&D Cycle Time," Research Technology Management, May-June 1994, pp. 27-32.

(table continued, next page)

People/Culture 1. Customer revalidation insufficient 2. Company's culture inappropriate 3. Teamwork inadequate 4. Creative encouragement inadequate 5. Employee profile incomplete	**Competitor** 1. Competitor intelligence insufficient 2. Competitor's capabilities unknown 3. Competitor's strategies unknown
Communication 1. Information flow inadequate 2. Technical services inadequate	**External efforts** 1. Regulatory impact unanticipated 2. Public sentiment misunderstood 3. Global diversity misunderstood

Source: Bob Burkhart, "Reducing R&D Cycle Time," Research Technology Management, May-June 1994, pp. 27-32.

Table 3. Potential Solutions to Uncertainty in Research

1. Enhance customer and market research resources and efforts	21. Outsource economically unfeasible products
2. Use market and competitor intelligence databases and consultants	22. Utilize valid product termination criteria
3. Assign staff to monitor competitors, patents, literature, society meetings, universities, federal labs, etc.	23. Practice open communication, participative management, and employee empowerment
4. Use formal documentation of customer and vendor interactions	24. Implement competitor countermeasures
5. Use multi functional teams to routinely validate needs/requirements	25. Utilize appropriate individual/team reward systems
6. Establish on-going interface with customers' and vendors' R&D organizations	26. Match personnel acquisition and utilization with strategies and priorities
7. Conduct market, customer and competitor training for staff	27. Establish opportunities for continuous professional education
8. Establish on-going interface with universities, federal labs, consultants, research institutes, etc.	28. Employ continuous improvement/TQM processes
9. Conduct needs discovery training	29. Utilize technical gatekeepers

(table continued, next page)

10. Conduct communications, team building and facilitator skill training	30. Utilize dedicated product stewards
11. Utilize technical team brainstorming	31. Utilize flexible budgeting
12. Maintain balance of long- and short-range R&D efforts in core technologies	32. Maintain positive contacts with influential groups, officials, agencies, etc.
13. Utilize SBU and R&D interfaces in project management	33. Maintain central reporting and data archiving system
14. Validate project criteria against company strategy	34. Account for teamwork in performance management system
15. Routinely evaluate marketing, manufacturing, and technology functional strategies	35. Utilize dedicated and competent regulatory, environmental and legal staffs
16. Routinely evaluate match of resources to projects	36. Initiate early examination of potential liabilities and regulatory issues
17. Initiate early prototype development	37. Maintain up-to-date response plan
18. Acquire businesses with the needed knowledge/resources	38. Maintain positive community outreach efforts
19. Develop joint ventures, alliances and cooperative and contract research agreements	39. Maintain proactive industry group involvement
20. Plan and execute coordinated market entry	40. Practice parallel project management

Source: Ibid.

As total quality management (TQM) practices were thought to render the most significant strategic advantages in the 1970s and 1980s, cycle-time reduction is believed to be the new wave that will carry world-class organizations from the end of this millennia into the next. As total quality management became a common practice, so will the practice of reducing cycle time. There is a new recognition that in the same way that a shorter product development cycle enhances a firm's ROI, reducing R&D cycle time helps a company to increase its ROI.

1.5 Cycle-Time-Related Findings of Previous Studies of ATP

Previous studies found that participants reported that the program had the effect of shortening their research and development (R&D) cycle time, enabling them to accelerate the development and commercialization of the technology.

Solomon Associates, in a 1993 report, found that sixty-nine percent (69%) of the first group of ATP awardees reported a significant shortening of the R&D cycle.[14]

Silber & Associates, in a 1996 report, found for 125 ATP participants, funded between 1990 and 1992 the following:[15]

(1) 95% of participants believed that the ATP award accelerated their progress.

(2) 74% anticipated shaving off a minimum of two years from the R&D cycle.

(3) 81% described speed to market as critically important or very important.

(4) 66% anticipated entering the market before the window of opportunity closes (not all respondents were involved in commercializing products or processes derived from their ATP-funded technology, for example, a given joint venture member might have a specialized research role only).

1.6 Further and More Focused Study of Impact on Applied Research Cycle Time Warranted

A review of these findings from earlier studies found that program participants believed that participation in the ATP program had supported them in their efforts to accelerate their technology development, but the studies – which addressed a broad and diverse set of performance metrics – did not provide details on cycle-time reduction. They did not go into *why* program participants felt that reducing cycle time was important; *how* participation in ATP had helped participants to reduce their cycle time; whether reducing applied research cycle time

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[14]Solomon Associates, The Advanced Technology Program, An Assessment of Short-Term Impacts: First Competition Participants, February 1993.

[15]Silber & Associates, Survey of Advanced Technology Program, 1990-1992 Awardees, Company Opinion About the ATP and Its Early Effects, January 30, 1996.

translated into shortening time to market; and whether there was carry-over to other operations. Nor did these surveys assign an economic value to reducing cycle time. The primary purpose of this case study was to gain a clearer understanding of these and other relevant issues pertaining to acceleration of technology development and commercialization.

CHAPTER 2
RESEARCH DESIGN

2.1 Research Methodology

Michael Quinn Patton's 1987 book, How to Use Qualitative Methods in Evaluation, provided useful guidance on the research methodology.[15]

To support the research design, the case study method was paired with user surveys. Both methods are viewed as appropriate to evaluate R&D projects that took place in the past, and both have their own strengths and weaknesses. For example case studies offer the advantage of providing detailed illustrations of the relationship between R&D and its impacts, but the disadvantage of generally providing no way to "add up" the results statistically for a more than anecdotal picture. User surveys, in contrast, generally provide more statistical evidence of impact across members of a group, but often lack the richness of detail needed to understand underlying relationships.[16] Pairing these methods allows the researcher to enrich the statistical treatment with detailed information about the hows and whys of applied research project acceleration.

This post hoc study assesses the impacts on cycle time of participating in the ATP, based on a telephone survey of the twenty-eight (28) 1991 ATP awardees. The twenty-eight awardees surveyed include 18 single company awardees and the lead organization of each of 10 joint venture projects. Together, the 28 projects in the sample comprise 10% of the projects the ATP has funded to date.

Nonparametric data on applied research activities, and parametric data on applied research cycle times were collected via telephone interviews. The collection of nonparametric data was intended to provide insights into how and why participation in ATP had reduced applied research cycle time for ATP program participants, while collection of parametric data was intended to allow the quantification and statistical evaluation of how much the cycle time had been reduced – and hence, to assess the degree of impact.

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[15]Michael Quinn Patton, How to Use Qualitative Methods in Evaluation, (Thousand Oaks, Calif.: Sage, 1987).

[16]David Mulcaster, Chairman, Methods for Assessing the Socioeconomic Impacts of Government S&T (Ottawa, Ontario, Canada: Working Group on S&T Financial Management and Mechanisms, May 1993), pp. ii-iii.

The interviews were structured so that the same set of questions were asked in the same order, so that themes could be easily discerned. The questions were asked in open-ended style and the interviewer simply recorded their responses without trying to match their comments to previously coded possible responses. The coding was performed after the interviews were completed.

Because interviewees were not provided with advance copies of the interview questions, their responses were more “top of head” and spontaneous in nature and tone. Interviewees were encouraged to be candid and forthright with their responses. They were assured that their individual responses would be without company or personal attribution.

2.2 Sampling Methodology

The study focused on 1991 awardees because the majority, having been awarded cost-sharing grants for a three-year period, were at or near the end of their active participation in the ATP program. Sufficient time had transpired to allow the impact of participating in ATP on applied research cycle time to have materialized and become apparent to program participants.

Table 4. Number of ATP Proposals, Number of Awards and Monetary Value of Awards, 1990 - 1996

Year	No. of Proposals Submitted	No. of Awards	Total Awards [$ million]
1990	249	11	46
1991	**271**	**28**	**93**
1992	140	21	48
1993	252	29	60
1994	595	88	309
1995	703	103	414
1996	308	8	19
Totals	2518	288 (11%)	989

Table 5. Taxonomy of 1991 Interviewees

Technology and Type of Lead Organization	Organization
Ten (10) Advanced Materials	
• 3 Small Companies	Cree Research, Inc., Nanophase Technologies Corp., Spire Corp.
• 3 Medium/Large Companies	Armstrong World Industries, Allied Signal Aerospace, IBM Corp.
• 3 Medium/Large Companies Leading JVs	Ford Motor Co., Honeywell, Westinghouse Electric Corp.
• 1 Non-Profit Research Institute	Michigan Molecular Institute.
Nine (9) Electronics	
• 4 Small Companies	American Superconductor Corp., AstroPower, Iterated Systems, X-Ray Optical Systems.
• 2 Small Companies Leading JVs	Conductus, Inc. and Spectra Diode Laboratories.
• 2 Non-Profit Consortia Leading JVs	American Scaled-Electronics Consortium, National Storage Industry Consortium.
• 1 Non-Profit Consortium	The Microelectronics Center of North Carolina.
Five (5) Biotech	
• 5 Small Companies	Aastrom Biosciences, Aphios, Biosym Technologies, BioSys, Engineering Animation.
Four (4) Manufacturing	
• 1 Small Company	Transitions Research Corp.
• 3 Non-Profit Consortia Leading JVs	Auto Body Consortium, National Center for Manufacturing Sciences, South Carolina Research Authority.

As shown in the taxonomy in Table 5, the 1991 ATP awardees can be classified in four major technology arenas: advanced materials, electronics, biotech and manufacturing technologies. Interviewees included those from small for-profit companies, medium- and large-sized for-profit companies, as well as non-profit industry consortia. ATP defines small business in the same way as the Small Business Administration – that is, as a business having fewer than 500 employees, but in fact, the majority of the small companies in the sample, and in ATP as a whole, are quite small, having fewer than 50 employees. (Details – project title, participant's name, location, and contact information are included in Appendix 2.)

2.3 Research Questions on Cycle Time

In evaluating the impact that the ATP program had on company applied research cycle time, the following eight questions were asked of the principal investigator for each project:

(1) How important is it for your company to reduce cycle time (time to market) ?

(2) Why is it important for your company to reduce applied research cycle time ?

(3) How much (by what percent change) did participation in the ATP affect your ATP project's applied research cycle time ?

(4) Do you expect the impact on cycle time in the applied research stage to flow through to other stages in the technology development life cycle ?

(5) Can you give a ballpark estimate of the economic value of reducing your cycle time by one year ?

(6) How were the cycle time improvements achieved ? (i.e., what did you do differently as a result of participating in ATP ?)

(7) Did the cycle time improvements (that were a result of participating in ATP) carryover to other technology development projects outside of the ATP project ?

2.4 Research Question on Applied-Research Performance Measures

An eighth question was also asked: "What applied research performance measures are tracked and assessed across applied research projects ?"

This open-ended question was asked in order to discover if and how companies were measuring applied research cycle time and/or other applied research performance measures.

CHAPTER 3
RESEARCH RESULTS

3.1 Interpretation of Results

The research results follow, organized as responses to the questions listed in section 2.3 preceding. The research results are descriptive in that they describe the impact that the ATP program had on the 28 awardees from the 1991 competition, as related by the principal investigator of each project's lead organization.

Despite limitations, descriptive analysis allows a researcher to analyze data and communicate the results without attempting to make a general statement or inference that goes beyond the particular individuals studied. In this study, descriptive analysis illustrates the Advanced Technology Program's impact on a group of awardees' applied research cycle time and suggests future lines of inquiry.

Research Results and Analyses

3.2 The Importance of Reducing Applied Research Cycle Time

96% STATED IT WAS VERY IMPORTANT FOR THEIR COMPANY TO REDUCE CYCLE TIME

Twenty-seven (27) or 96% of the 28 interviewees indicated that it was "very important" for their companies to reduce cycle time, while one (4%) indicated that it was "important." Specific terms used by the interviewees to answer the question, "How important is it for your company to reduce cycle time ?" – all of which were characterized by the author as denoting "very important" – were the following:

(1) "Very important."

(2) "Extremely important."

(3) "Obviously very important."

(4) "One of our most important corporate imperatives."

(5) "Critically important."

(6) "Critical to our future."

(7) "Absolutely critical."

(8) "A must."

These results are consistent with findings from an open literature review that found that cycle-time reduction was viewed as important because it enhances a company's global competitiveness and helps a company to better achieve its performance goals. These results are also consistent (though not identical) with the findings from the recent survey conducted by Silber & Associates.[18]

3.3 Reasons to Reduce Applied Research Cycle Time

THE MOST FREQUENTLY GIVEN REASON TO REDUCE CYCLE TIME WAS TO MEET COMPETITION

When the twenty-eight interviewees were asked "Why is it important for your company to reduce cycle time ?", most gave more than one reason. As a result, there are more than 28 responses.

There is obvious overlap among the types of reasons given, but in order to preserve the flavor of the responses, these have been kept separate rather than merging them under umbrella headings.

(1) Meet Competitive Challenge [12 interviewees]

Reducing cycle time and being first to market with technological innovations and new products provides one with a competitive advantage. One interviewee stated, "Hitting the market first – with a viable product – gives you a chance to be more competitive and successful. It gives you a significant leg-up."

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[18]Silber & Associates, Survey of Advanced Technology Program, 1990-1992 Awardees, Company Opinion About the ATP and Its Early Effects, January 30, 1996.

Another interviewee said that his company had "faced very strong competition from the Japanese. They have a much shorter cycle time." He went on to say, "we may have a similar cost structure but our cycle times are two to three times longer. It is critical that we reduce cycle time if we are to be competitive with them."

(2) Satisfy Customers [9 interviewees]

Nine interviewees all mentioned the following points relating to the impact of reducing applied research cycle time on customer satisfaction:

- Enhancing customer satisfaction.
- Reacting to voice of customer more quickly.
- Meeting wants and desires of customer.

(3) Attract Additional Capital [8 interviewees]

Many of the program interviewees spoke of a stage in the technology development life cycle that is not reflected in the literature – that is the "capitalization stage." Cash infusions are critical to these innovators and inventors who need capital to fund their high-risk technologies.

Eight interviewees stated that reducing applied research cycle time helps them to acquire "elusive and shrinking" R&D dollars.

One interviewee pointed out that it is only possible to acquire venture capital and financial support for a new technology and/or new product that have/has well-defined risk, well-defined value, and well-defined time to market. He stated, "for new technology development, you can only have so many years and so many dollars available for early stage development until a project must be self-supporting. You must clear the threshold and you must show that you have something real. If you don't hit the threshold, you don't get the funds."

A second interviewee stated, "reduced cycle time shows that you are on the forefront of technology development, establishes credibility with venture capitalists and ensures future financing."

A third interviewee expressed this concern, "if we don't get products out soon, venture capitalists will lose interest and pull out. We have a critical need to get something out in the next decade."

(4) Enhance Technology Development Process [7 interviewees]

Seven interviewees stated that reducing cycle time enhances the technology development process by accelerating the development of technology to the point where it can be utilized, leveraged and commercialized. "Results are more likely to be realized."

(5) Reduce Costs [6 interviewees]

Six interviewees cited cost reductions from cycle-time reduction.

One interviewee stated, "Reducing cycle time saves dollars in a big, big way. When you get a product to market six months earlier, it generates many, many millions of dollars in cost savings." Other interviewees said that with a reduced cycle time:

- The development cost is lower.
- The initial cost of new and improved versions is lower.
- The labor cost is reduced.
- The cost of capital is lower because of the time value of money.

(6) Survive [5 interviewees]

Five interviewees stated that cycle time and time to market affects their ability to survive.

One interviewee stated, "Cycle time is an issue we wrestle with. We've learned that the superior technology doesn't always win the game . . . Sometimes, it's the company with the lower cycle time."

A second interviewee stated, "The faster, the better. Anything that will help us do it faster, the better off we are."

A third interviewee stated, "It means 'life' or 'death' for us. 'Go' or 'no go.' Reducing cycle time is necessary to being a viable organization. Fast, we survive; slow, we don't. Entering the market during the window of opportunity is a 'make' or 'break' decision – not only for us in this product class, but for us as a company."

(7) Enhance Quality [5 interviewees]

Five individuals pointed out that production quality is enhanced by shorter cycle times. Intuitively, one might expect production quality to be enhanced by longer cycle times, not shorter cycle times. Though the responses may seem counter-intuitive, one interviewee explained that "Quality is married with cycle time. The two metrics are related. Especially in the hand-off from design to manufacturing. Process is dramatically improved. It becomes a collaborative environment. Manufacturers get to use design at the time of design rather than post hoc. Quality of the product is enhanced by shorter design and engineering lead time – engineers are able to introduce changes that enhance the design or the product. In the past, with the older, longer cycles, engineers would have to compromise."

(8) Increase Return on Investment (ROI) [5 interviewees]

Five interviewees stated that reducing cycle time increases return on investment.

Several interviewees pointed out that reducing cycle times will help their companies more quickly achieve long-term, industry-wide results necessary to hitting their corporate financial benchmarks.

(9) Respond to Changing Market [3 interviewees]

Three interviewees stated that reducing cycle times would make it easier to survive in their "turbulent," "highly unstructured" market places.

(10) Dominate Market [3 interviewees]

Three interviewees reflected one interviewee's thought that: "If you're the first one there with a bug-free technology, you have a chance of establishing market dominance – and can then set the bar for everyone else."

(11) Reduce Risk [3 interviewees]

Three interviewees thoughts were captured by one who said: "Greatly reducing cycle time on the initial product and on subsequent products increases net present value, and decreases uncertainty and risk."

(12) Grow [2 interviewees]

Two interviewees reflected the sentiment that "Cycle-time reduction allows us to develop new business and new jobs."

(13) Increase Sales Volume [2 interviewees]

Two interviewees stated that when you're the first to market and one year in advance over your competition, sales volume goes up.

(14) Increase Market Share [2 interviewees]

Two interviewees reflected sentiments that for any technology, it's important to reduce applied research cycle time if you don't want to lose your chance at increasing market share – and those who are first to market have a differential advantage in terms of increasing market share.

(15) Combat Perceived Weakness [2 interviewees]

Two interviewees stated that applied research cycle-time performance was perceived as a weakness in their respective companies.

The first stated, "Reducing applied research cycle time is critical in starting a new company. Part of the reason we merged with another company is that we didn't do a good job on applied research cycle time."

The second stated, "Though our company is recognized for having great technology performance, we are also recognized for our poor applied research cycle time. For the last one-and-a-half-to-two years, reducing applied research cycle time has been greatly emphasized and is now an important metric in our company."

(16) Develop Critical Capability [2 interviewees]

Two interviewees acknowledged that their companies were trying to reduce applied research cycle time to develop a critical capability. The first stated, "Applied research cycle-time reduction is critical for our product class. Our company is trying to develop this capability." The second interviewee echoed this sentiment by stating: "It is absolutely critical to do it as quickly as possible; to try something new; and to operate in a short technology development and product development cycle time."

(17) Take Advantage of Window of Opportunity [2 interviewees]

Two interviewees respectively made the following statements: "Commercial windows are shortening," and "If you take too long, you're obsolete before you come out with the product."

(18) Collaborate [2 interviewees]

Two interviewees linked reducing applied research cycle times to enhancing collaboration. Because applied research cycle-time reduction requires a systemic and integrated approach, people from different sub-systems must work with each other and end users.

(19) Choice of Competitive Strategy [2 interviewees]

Two interviewees mentioned that reducing applied research cycle time opens up strategic choices. The first observed, "When companies are not first to market, they beat their brains out with price cuts in order to establish market share." The second observed, "Reducing cycle time enables companies to choose a higher performance strategy, instead of a price-cutting strategy. Higher performing companies tend not to engage in price wars."

(20) Maintain Technical Leadership [1 interviewee]

One interviewee felt that being first to market with a new technology was critical to maintaining technical leadership. "Our company had a competitive advantage - we were the technical leader and were perceived as such. We were known for our science. But, we also needed to be first to market in order to maintain position as technical leader."

(21) Establish Intellectual Property Rights [1 interviewee]

One interviewee pointed out that, "Technology has a finite protected life. The more rapidly you can get into the marketplace, the longer you can operate with U.S. patent protection and other forms of intellectual property rights protection."

(22) Follow Industry Practice [1 interviewee]

> One interviewee stated, “In our industry, applied research cycle times have been dropping; cycle times are now measured in months instead of years.”

The finding that the most frequently given reason to reduce applied research cycle time was to meet competition is consistent with the paramount finding from the literature review that cycle-time reduction is important because it enhances global competitiveness.

3.4 Impact of ATP Participation on Applied Research Cycle Time

PARTICIPATION IN THE ATP REDUCED THE PROJECTS' APPLIED RESEARCH CYCLE TIME BY 50% OR THREE YEARS

After being asked, “How much (by what percent change) did participation in the ATP affect your ATP project’s applied research cycle time ?”, the median response of the twenty-eight interviewees was that participation in ATP reduced their ATP project cycle time by 50% or three years (see Table 6). The median response was that without ATP, the same project would have taken six years. In terms of years saved, the range was from 1 to 2 years at the low end, to 10 years and more (infinity) at the high end. In terms of percentage cut in cycle time, the range was 25% to 80%.

Five of the 28 interviewees challenged the question. They said that a more relevant question was, “Would you have done the applied research at all without ATP support ?”. They attributed the entire existence of the project to participation in ATP; with an “infinite” impact on the applied research cycle time. As one interviewee stated:

> “The business environment is now more short sighted. It is more hesitant to put capital into technology development projects; and to apply technology once it is developed. Given the past three-to-four years, it’s fair to say we wouldn’t have started or pursued this research without ATP funding.”

These five interviewees,which included companies of all sizes, said they could not bound the reduction in applied research cycle time because they would not have ever begun without the ATP award.

Table 6. Impact of ATP Participation on Applied Research Cycle Time

Rank Order by % Reduction	% Reduction	Number of Years Shorter
(1) small	*	unbounded
(2) small	*	unbounded
(3) medium/large	*	unbounded
(4) medium/large	*	unbounded
(5) medium/large	*	unbounded
(6) small	75 to 80%	10 years shorter
(7) medium/large	66-75%	6 to 9 years shorter
(8) small	50-66%	5 to 6 years shorter
(9) small	50-60%	at least 5 years shorter
(10) small	50%	5 to 6 years shorter
(11) small	50 %	5 years shorter
(12) small	50%	5 years shorter
(13) medium/large	50%	5 years shorter
(14) small	**50% MEDIAN**	**3 years shorter**
(15) small	**50% RESPONSE**	**3 years shorter**
(16) medium/large	50%	3 years shorter
(17) medium/large	50%	3 years shorter
(18) medium/large	50%	3 years shorter
(19) medium/large	50%	3 years shorter
(20) medium/large	50%	3 years shorter
(21) medium/large	50%	2 years shorter
(22) medium/large	50%	2 years shorter
(23) small	50%	1.5 years shorter
(24) small	50%	1.25 years shorter.
(25) small	33-50%	1 - 2 years shorter.
(26) small	33%	2 years shorter
(27) medium/large	30%	3-5 years shorter.
(28) medium/large	25%	2 years shorter.

* These companies were unwilling to bound their estimated cycle-time reductions because they said they wouldn't have ever started without the ATP award.

It is interesting that many of the interviewees' responses to this question are so similar, particularly since the interviewees come from different kinds of organizations, different sizes of organizations, and different types of industries.

3.5 Flow-Through of ATP's Impact on Applied Research Cycle Time to Later Stages in the Technology Development Life Cycle

86% OF THE INTERVIEWEES EXPECT THE IMPACT ON CYCLE TIME IN THE APPLIED RESEARCH STAGE TO FLOW THROUGH TO OTHER STAGES IN THE TECHNOLOGY DEVELOPMENT LIFE CYCLE

When asked, "Do you expect the impact on cycle time in the applied research stage to flow through to other stages in the technology development life cycle ?", twenty-four (24) or 86% of the 28 interviewees said yes. One interviewee suggested that this is better described as a cascade effect, not a flow, since it is not linear. He described it as a driving force that has a broad effect. This implies that, at least in some cases, speeding up the R&D may have a disproportional impact on the later stages in technology development.

Of the four interviewees who did not give a clear yes to the question, one said "probably yes", but that he wasn't sure, and three said that it was not applicable. Two of those provided the following reasons for the lack of applicability of the question:

> "We only do technology development. We get a commercial partner interested and transfer technology to them. The intellectual property revenue stream seeds and funds internal R&D."

> "The applied research only advanced to the demonstration stage. That's when market analysis revealed that new competitive challenges in the marketplace had rendered our applied research obsolete. As a result, we did not advance the applied research beyond the demonstration stage."

A careful review of the literature did not yield many articles that touched specifically on the flow-through of applied research cycle-time savings to later stages in the technology development cycle. Most of the R&D evaluations conducted by industry, government, academia, and science over the past four decades have focused on the short-term; few studies have directly linked research inputs to research outputs and research outcomes.

If there were neither flow-through nor linkage between research cycle-times and the long-term commercial outcomes, then there would be no market-place benefit associated with reducing applied research cycle time. If, on the other hand, there is a flow-through or linkage, then the potential for accelerated long-run economic benefits – that as a consequence may be larger both in present value terms and in nominal terms (due to competitive advantages) – exists from shortening the research phase. Common sense would cause us to expect a flow-through of time savings from the earlier stages to the later stages, and, indeed, this study found that most of the interviewees expected the impact on research time to flow through to later stages in the technology development and commercialization cycle. Though this study makes the anticipated linkage, the impact of earlier-stage time savings to the timing and size of longer-term outcomes needs to be more fully explicated.

3.6 Economic Value of Reducing Applied Research Cycle Time By One Year

79% OF THE INTERVIEWEES GAVE "BALLPARK ESTIMATES" OF THE ECONOMIC VALUE OF REDUCING APPLIED RESEARCH CYCLE TIME BY ONE YEAR

When asked, "Can you give a 'ballpark estimate' of the economic value of reducing applied research cycle time by one year ?", twenty-two (22) or 79% of the 28 interviewees gave either a quantitative or qualitative "ballpark estimate." Fifteen (15) or 54% of the 28 interviewees gave a quantitative estimate. Seven (7) or 25% of the 28 interviewees gave a qualitative estimate. Some of the interviewees who provided quantitative responses also provided qualitative responses.[19]

Even though interviewees estimated that participating in the Advanced Technology Program helped them to reduce their applied research cycle time anywhere from one to 10 years, all were asked to give the economic benefit associated with just a one-year reduction. The estimates are therefore much more conservative than if they had been asked to estimate the total value of the realized cycle-time reduction. The estimates range from one million dollars to "billions" for a one-year reduction in applied research cycle time and appear to relate specifically to the direct economic values to the company or JV member companies rather than to the potential broader benefits that might be realized. The estimates in Table 7 are listed in order of the size of the value, with the largest estimated value listed first. The median estimate of the economic value of reducing the applied research cycle time by just one year is $5 million to $6 million.

[19] This is why there are more than 28 responses in total.

Table 7. Ballpark Estimates of Economic Value of a One-Year Reduction in Applied Research Cycle Time, In Order of Decreasing Value

Type of Organization	Economic Value of Getting to Market One Year Sooner	Nature of the Economic Value
(1) medium/large	$100's of millions to billions	sales revenue
(2) medium/large	$1 Billion	sales revenue
(3) medium/large	$100 to 200 million	sales revenue
(4) small	$15 to 250 million to ultimately ½ billion	sales revenue
(5) small	$10 to 100 million	sales revenue
(6) small	$10 to 30 million	sales revenue
(7) medium/large	$15 million	sales revenue
(8) small	**$5 mil. to $6 mil MEDIAN VALUE**	**sales revenue**
(9) small	$5.2 million	capital cost savings
(10) medium/large	$2 to 5 million	sales revenue
(11) small	Millions of dollars	sales revenue
(12) small	Millions of dollars	sales revenue
(13) small	Millions of dollars	sales revenue
(14) medium/large	$2 million	sales revenue
(15) small	$1 to 2.25 million	sales revenue and cost savings

The qualitative estimates of cutting research by one year – like the quantitative estimates – centered on sales revenue and cost savings. Five interviewees discussed financial impacts associated with tripling the revenue stream, increasing sales, reducing penalty costs, reducing environmental costs, reducing legal costs, reducing cost of capital, and becoming profitable at an earlier time. Eight interviewees provided qualitative perspectives on market impacts in terms of commercializing applications, having a broader impact on the whole industry, keeping the product current, accelerating results, and making it possible to increase market share and establish market dominance.

One interviewee – speaking for a joint venture project – in discussing the value of reduced cycle time stated:

> "Three companies have commercialized applications of the technology developed in ATP. But there has been a broader impact on the whole industry, which has advanced to

a higher level because of ATP. This would not have been taken on without ATP's funding and risk-sharing."

Another interviewee – speaking for a single-company project – stated:

"With the ATP project, we will create a new market and be associated with it. This will lead to an increase in our market share. If we came in a year later, competing for market share would be more difficult. With the market share, we anticipate generating a positive cash flow one year after product introduction."

Six (6) or 21% of the 28 interviewees who said, "No, I can not give a ballpark estimate," gave the following reasons:

(1) "It's very difficult, if not impossible for me to do that."

(2) "It's hard to quantify or qualify the gains."

(3) "As a component manufacturer, we are an enabler and supporter of systems manufacturers. As a result, we are not sure what level of economic value is generated."

(4) "That's very hard. We sell 2-3 million systems not 1-2,000 products. We provide customers with capabilities and solutions to problems. Though I cannot quantify the benefits, I can say that they are significant and global."

(5) "It's nebulous. The technologies we developed are not yet faced with competitive issues. We offer new solutions and are looking for problems to solve."

(6) "The configuration of the industry changed and the basis of competition moved from one technology platform to another. As a result, the economic opportunity disappeared and we did not commercialize the technology we were developing in the Advanced Technology Program."

It is perhaps surprising that so many of the interviewees (a majority of 22 or 79% of the 28 interviewees) were willing to give a "ballpark estimate" of the economic value associated with reducing their applied research cycle time by one year. It was expected that the majority of the respondents would not be able/willing to give a "ballpark estimate".

Not only did most of the interviewees appear very comfortable providing estimates, it is the researcher's opinion that if the remaining interviewees had been encouraged to provide an estimate most would have done so. But since the intent was to capture their initial responses to the question, freely-given, the interviewees were not pushed to generate estimates.

3.7 ATP Effects that Helped Reduce Applied Research Cycle Time

THE MOST-FREQUENTLY MENTIONED ATP EFFECT THAT HELPED REDUCE CYCLE TIME WAS ATP'S REQUIRED PROJECT PLANNING AND MANAGEMENT.

When the twenty-eight (28) interviewees were asked: "How were the cycle-time improvements achieved, in other words, what did you do differently as a result of participating in ATP?", they gave 58 answers. When the answers are grouped by the type of ATP practice that helped interviewees reduce cycle time, we find that there are five major ATP categories. Table 8 shows aggregate total frequencies and percentages.

Table 8. ATP Effects that Helped Interviewees to Reduce Cycle Time

ATP Effects that Helped Interviewees to Reduce Cycle time	Frequency of mention	%
ATP's Required Project Planning and Management	15	25.86%
Achievement of Critical Mass of Resources With ATP Funding	12	20.69%
Attraction of Additional Financial Support through ATP "Halo Effect"	12	20.69%
Greater Project Stability Through Focus on Technical Problem	12	20.69%
ATP's Emphasis on Collaboration	7	12.07%
TOTAL	58	100.00%

(1) ATP's Required Project Planning and Management [15 interviewees]

For this sample of 28 interviewees representing 28 projects from the 1991 competition, the detailed project planning that ATP required and the project management it provided to ensure that companies followed the project plan were most frequently cited as the ATP effect that helped interviewees to reduce cycle time. It was felt, in general, that the well laid-out plan required by ATP from the companies lent stability to the applied research program. According to one interviewee:

> "Of greatest value, with ATP we had a well-laid-out plan, and followed the plan without interruption. Without the ATP plan, the vagaries of our business would have caused us to vary the plan. If we were not having a good year financially, we would probably have pulled the plug – but ATP's involvement lent stability to the research program."

ATP's requirement for an integrated business and R&D plan with its emphasis on concurrent engineering seemed to speed things up. This was described by one interviewee:

> "For us, product testing typically comes later in the product development cycle. ATP wanted us to work early-on with potential customers and users. One of our primary interests from the very beginning was to work with potential users. We wanted to work in a 'true manufacturing envelope' with 'true manufacturing equipment.' ATP made this happen."

Other project planning and management techniques that were said to be important to cycle-time reduction and attributed to the ATP involvement included: using a systematic approach; developing definable time lines and value; bench marking and selecting technology applications; integrating the voice of the customer; assuring quality; and enhancing documentation procedures.

(2) Achievement of a Critical Mass of Resources Through ATP Funding [12 interviewees]

ATP funding was important to applied research cycle-time reduction because it enabled interviewees to gain the critical mass of resources necessary to conduct the applied research. This was mentioned by interviewees from small for-profit companies, medium-to-large for-profit companies, and non-profit consortia. For most interviewees, this meant increasing staffing, but a couple mentioned material resources, and one said that the company was able to more fully dedicate existing staff to the applied research project.

An interviewee from a large company stated: "Major companies are structured into decentralized divisions – each little fiefdom (division) has a budget. Our division didn't have adequate funding to pursue this project."

An interviewee from a small company stated, “ATP enabled us to acquire a critical mass of resources. The corporation has limited resources. We looked around. We wouldn’t have have had enough resources to reach critical mass to develop and leverage resources. As a small company, we wouldn’t have been able to do the R&D, period.”

(3) Attraction of Additional Financial Support through ATP “Halo Effect” [12 interviewees]

Some interviewees mentioned their improved ability to stimulate interest and acquire capital to continue pursuing their advanced technologies as an important ATP effect on cycle time. The additional infusion of capital was said by some to have been critical. Many of the scientists and engineers appear to have taken on an entrepreneurial role to support and speed the development of their technology.

A few of the comments about the effect of attracting additional capital on reducing applied research cycle time follow:

> “There is a question in our minds as to where we would have gotten funding, and a question as to whether we would have survived. We didn’t round up private funding until after we got ATP funding. It’s a high-risk project, and we had previously operated by bootstrapping, which would not have lasted long.”
>
> “If we had not had ATP funds, we would have had to attract capital. That would have been difficult without ATP. With ATP, we got press and were able to generate excitement. It easily halved the development time.”
>
> “We were able to leverage ATP participation to quickly acquire additional funding. Selection as an ATP project resulted in the perception that we were a viable organization. We were able to get new venture capital for other technology projects, programs, and platforms.”

(4) Greater Project Stability Through Focus on Technical Issue [10 interviewees]

Six interviewees commented that participating in the ATP enabled them to shorten the applied research cycle time by allowing them to concentrate on solving the technical problem.

One large company interviewee said that:

> "The ATP contract allowed an R&D group to do enough work on a technology to go to other people in a large company with more than a prototype. The company was reducing the R&D budget and manpower; and the ATP support was critical because it allowed us to focus on the technology problem, rather than the organizational problem."

Another large company interviewee said that:

> "The technology development wouldn't have happened without ATP. The ATP was really a catalyst. The match was not only important from a financial standpoint but from a strategic standpoint as well. What is most difficult for us in a large bureaucracy is to get the snowball started and that's what ATP helped us to do."

A small company interviewee said that:

> "The ATP gave us the ability to make certain mistakes in research – participating allowed us to proceed in an orderly, "unpanicked" way."

(5) Enhanced Collaboration [6 interviewees]

Six interviewees said ATP enhancement of collaboration helped reduce the applied research cycle time. Four interviewees explained that:

> "ATP brought strange bedfellows together – who were competitors. ATP also brought members of the supply chain together to define what they needed in the supply chain. As a result, it helped us and other members of the supply chain to move further, faster."

> "Perhaps most importantly, ATP brought competing companies together. This would not have otherwise happened. They never would have worked with each other without ATP. Within mega-corporations, there is oftentimes much personal competition between the senior executives. The benefit of a joint venture is that senior executives from different companies are sometimes more willing to share ideas with executives from other companies than with peers in their own organization. This enhances the innovative thinking and collaborative processes. The members of the ATP joint venture were so compatible with each other that

> they moved smoothly like a dance team – it got to the point that in meetings that they were building on each other's words and finishing each other's sentences."

> "Beyond enhancing collaboration between competitors, ATP enhanced collaboration between technology developers and technology purchasers. We developed the technology in a joint venture partnership. Two of our partners didn't want to buy R&D directly from us, but they wanted to invest in our technology development under the auspices of ATP."

> "Through ATP, we structured a mutual win-win with a joint venture partner that had a complementary set of technology skills that enabled both of us to develop the technology more quickly."

Robert Cooper, in a 1994 article, stated that the four factors that had the greatest impact on time efficiency in new product development (in order of priority) were (1) a strong organization and resource management, (2) a strong market orientation, customer focus and execution of marketing plans, (3) strong planning and decision making, and (4) strong technology and project management. These are listed in Table 9 with an indication of the relative importance of their impacts on time efficiency and time schedule. Of course, the comparison with the ATP interviewee responses is not perfect: the focus of Cooper's research was on product development, rather than the earlier applied research stage which is the focus of this study. Furthermore, he was concerned about factors the organization could bring to bear on cycle time, whereas the focus of the responses in this study was on factors the ATP brought to the equation. But the themes of planning, bringing in business functions early, and strong management seem common to both.[19]

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[19] Robert G. Cooper, "New Products: The Factors That Drive Success," International Marketing Review, Vol. 11, No. 1, 1994, p. 60-76.

Table 9. Drivers of Cycle-Time Reduction in Product Development (Not Based on ATP Awardee)

Driver of Cycle-Time Reduction (rank ordered)	Impact on Time Efficiency	Impact on Adherence to the Time Schedule
Strong Organization. A cross-functional team; accountable, empowered, dedicated, clear leader, with top management support. Resource Management.	Strong impact (0.316)	Very strong impact (0.527)
Strong Marketing Function. A strong market orientation and customer focus; and quality of execution of marketing actions.	Strong impact (0.308)	Very strong impact (0.411)
Strong Planning & Decision-Making. Undertaking the homework up-front – before development begins.	Modest impact (0.226)	Strong impact (0.478)
Strong Technology Management. Quality of execution of technological activities (technical assessment; development; lab tests; trial production; production start-up, project management).	Modest impact (0.223)	Strong impact (0.331)

Source: Robert G. Cooper, "New Products: The Factors That Drive Success," International Marketing Review, Vol. 11, No. 1, 1994, pp. 60-76.

The finding that ATP's required project planning and project management support was mentioned more frequently than its funding support for this particular sample of program participants, though not statistically significant, is suggestive. It highlights one of the unusual characteristics of this governmental program: it does more than disburse funds, it requires both R&D and business advance project planning, and it monitors project progress against both technical and business goals, over the multi-year project life. ATP views the companies as partners in the technology development process and takes an active role in overseeing how the projects are carried out. As a result, the relationship between the "partners" (ATP and the awardee organizations) entails a detailed technical and business review by ATP of the proposed project, with feedback to the proposer; rigorous competition among proposers against published selection criteria; and a kick-off meeting where technical milestones and business goals are further reviewed and detailed. The kick-off meeting is followed by quarterly reports and annual reviews until the project is completed. Failure to perform can lead to project termination. Then, there is post-project tracking of further developments. This active participative role appears to be the reason why ATP was viewed by the interviewees as strengthening their planning for technology development, enhancing strategic focus, and providing stability to see the job through.

It is interesting to note that there are two types of acceleration implied in the responses. One relates to overcoming delays in starting technology development projects. The other relates to speeding up performance of the research once it is underway. The ATP funding seems to have played a critical role in overcoming the inability to get the projects off the ground. The advance technical and business planning requirements, project oversight to hold it on course, and research efficiency gains from collaboration – in addition to the funding – seem to have been critical factors in speeding up the research once the projects began.

3.8 Carryover of Cycle-Time Improvements Resulting from ATP Participation to Non-ATP Applied Research Projects

86% STATED THAT CYCLE TIME IMPROVEMENTS THAT RESULTED FROM PARTICIPATING IN ATP CARRIED OVER TO OTHER TECHNOLOGY DEVELOPMENT PROJECTS

When the twenty-eight interviewees were asked: "Did the cycle-time improvements that were a result of participating in the ATP carryover to other technology development projects ?", twenty-four (24) or 86% of the 28 interviewees said yes; three (3) or 11% said no; and one (1) or 3% said they didn't know if cycle-time improvements "carried over." Most of the interviewees explained ways in which the ATP-fostered cycle-time reductions were transferred to other technology development projects. These responses are listed in Table 10, grouped by nature of response and placed in order of total frequency of mention.

Table 10. Carryover of Cycle-Time Improvements to Other Projects

Type	Carryover of Cycle-Time Improvements	Fre-quency	%
(1)	Yes - Enabling, Generic, Precompetitive Technology	9	32.14%
(2)	Yes - Adopting "ATP Practice" to Related Projects	6	21.44%
(3)	Yes- Extended Adoption of New Methodologies and Processes	4	14.29%
(4)	Yes- Cultural Change	2	7.14%
(5)	Yes - A Little	3	10.71%
(6)	No	3	10.71%
(7)	Don't Know	1	3.57%
	Total	28	100.00%

(1) "Yes, Enabling, Generic, Precompetitive Technology" [9 interviewees][21]

Nine interviewees, or 32% of the sample, said that cycle-time improvements that were a result of participating in ATP were carried over to other technology development projects because the ATP resulted in an enabling technology that had broader applications that allowed them to speed up other projects. Two different interviewees explained this well:

> "Through ATP, we built a better understanding of technology. We can spin-out products at a faster rate because we have a fundamental understanding of core technology with multiple applications."

> "It turned out that the technology we were developing through ATP had utility for other applications. It has become a technology platform for other applications."

(2) Adopting "ATP Practice" to Related Projects [6 interviewees]

Six (6) interviewees, or 21% of the sample, said that cycle-time improvements resulting from their ATP participation were carried over to related projects within the company, with other government organizations, and with industry because they are applying ATP-required planning and project management practices to other projects. One interviewee explained:

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[21]Note that this effect could also be viewed in the context of intra-firm spillovers and economies of scope.

"Our organization has changed. We were once a small independent research entity – but things have changed significantly. We've received a large contract from industry. These independent development efforts with ATP and with industry are similar in nature. The ATP cultural imperative and requirement that experiments be written up in a rigorous fashion did have an impact – we are giving the write-ups to an archivist; and we are using similar methods on our industrial contract. We do not have a separate quality assurance department, but following the ATP practice, we have embedded quality into our day-to-day work habits."

(3) "Yes, Extended Adoption of New Methodologies and Processes" [4 interviewees]

Four (4) interviewees, or 14% of the sample, reported that cycle-time improvements were enabled by the adoption of new methodologies and processes resulting from their ATP participation. Two interviewees explained . . .

"Peer pressure being what it is, once two groups come up with a way to reduce cycle time – others immediately find out what is going on and apply the new methodology to their own group."

"We used ATP funds to do process development. It was a building block for other developments. We now have a reliable base to build on and benefit from the cumulative effects."

(4) "Yes, Cultural Change" [2 interviewees]

Two (2) interviewees, or 7% of the sample, believed that the cycle-time improvements that were a result of participating in ATP resulted in a cultural change that carried over to other projects.

Quoting one:

"By doing this on a faster speed in the ATP project, we built a culture that expects to do things faster. By focusing on long-term needs, it allowed us to better manage short-term needs."

(5) "Yes, A Little." [3 interviewees]

Three (3) interviewees, or 11% of the sample said, "Yes, the cycle-time improvements were carried over 'a little,' in other words, to a minimum extent," but didn't elaborate as to how.

(6) "No, No Change." [3 interviewees]

For the three (3) interviewees, or 11% of the sample, who said that cycle-time improvements were not carried over, they attributed the lack of carryover to internal organizational dynamics. For example, one interviewee stated:

> "No – but our company is going through a series of changes – we're restructuring every operation into decentralized units. The company is breaking up into smaller units. This reduces opportunity for cross-fertilization. In another organization with a more centralized research system, more benefits could have been derived. This is frustrating because the potential existed but could not be realized."

(7) "Don't know." [1 interviewee]

One interviewee, or 3.6% of the sample, said they didn't know if there was a carryover to other projects.

When ATP practices result in cycle-time improvements that are carried over, we can say that to some extent, these practices have been institutionalized. In fact, this study found that the representatives for the lead-company awardees thought that ATP-originated practices were, for the most part, carried over, (hence institutionalized). Interviewees attributed the carry-over to the enabling technologies that positioned the companies to execute a number of subsequent spin-off activities faster; to the use on related projects of ATP-acquired practices that foster project acceleration; to the wider application of new methodologies and new processes that reduce cycle time; and to cultural changes associated with adopting a faster pace as a way of life. They discussed how participating in the ATP program enabled them to remove organizational barriers to cycle-time reduction. But beyond brief characterizations, they did not provide much detail. To the extent that other work in the ATP-funded companies was accelerated by the companies' participation in the ATP, the benefits of ATP on the participating companies may be systemic in nature and greater than anticipated.

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APPENDIX 2: ATP PROJECTS AND INTERVIEWEES

1991 ATP Project Title and Interviewees
SINGLE-COMPANY APPLICANTS
Human Stem Cell and Hematopoietic Expansion Systems Aastrom Biosciences, Inc. P.O. Box 376 Ann Arbor, MI 48106 [small for profit] Doug Armstrong 313-930-5555
High Temperature Superconducting Racetrack Magnets for Electric Motor Applications American Superconductor Corp. (ASC) 2 Technology Drive Westborough, MA 01581 [small for profit] Bruce Gambol 508-836-4200, x207
Low Temperature Viral Inactivation Aphios 3-E Gill Street Woburn, MA 01801 [small for profit] Trevor Castor 617-932-6933

Thermal Insulation Materials - Morphology Control and Processes for the Next Generation of Performance. Armstrong World Industries Innovation Center R&D 2500 Columbia Ave Lancaster, PA, 17603 [medium/large for profit] Arthur Yang 717-396-5201.
Manufacturing Technology for High Performance Optoelectronic Devices Based on Liquid Phase Electro-Epitaxy AstroPower, Inc. Solar Park Newark, DE 19716-2000 [small for profit] Jim McNeely 302-366-0400
A Feedback-Controlled Metalorganic Chemical Vapor Deposition Reactor Spire Corp. One Patriots Park Bedford, MA 01730-2396 [small for profit] Nassar Karam 617-275-6000, ext. 306

Autonomous Navigation in Quasi-Structured Environments Transitions Research Corp. Shelter Rock Lane Danbury CT 06810 [small for profit] Joseph Engleberger 203-798-8988
Development and Applications of Density Functional Software for Chemical and Biomolecular Modelings Biosym Technologies, Inc. 9685 Scranton Road San Diego, CA 92121 [small for profit] Arnold Hagler 619-546-5514
U.S. Self-Sufficiency in High-Quality Pyrethrin Production (Agridyne Technologies was acquired by BioSys) BioSys 10150 Old Columbia Road Columbia, MD 21046-1704 [small for profit] Dr. Jeff Kelly

Integrated Force Array The Center for Microelectronics at MCNC P.O. Box 12889 3021 Cornwallis Rd. Research Triangle Park, NC 27709-2889 [non profit] Scott Goodwin-Johannason 919-248-1964
X-Ray and Neutron Focusing and Collimating Optics. X-Ray Optical Systems, Inc. 90 Fuller Road Albany, NY 12205 [small for profit] David Gibson 518-442-5250
Advancement of Monocrystalline Silicon Carbide Growth Processes Cree Research, Inc. 2810 Meridian Pkwy, Ste 176 Durham, NC 27713 [small for profit] Calvin Carter 919-361-5709

A Three-Dimensional Database for Visualization of Human Physiology Engineering Animation, Inc. Iowa State Univ. Research Park 2625 N. Loop Dr. Ames, Iowa [small for profit] Mike Sellberg 515-296-6931
Novel Near-Net-Shape Processing of Engineered Ceramics Garrett Ceramic Components, a unit of Allied-Signal Aerospace 2525 W. 190th St. Torrance, CA 90509 [medium/large for profit] John Pollinger 310-323-9500
Polymeric Switches for Optical Interconnects IBM Corp. Almaden Research Center 650 Harry Road San Jose, CA 95120 [medium/large for profit] Don Burland 408-927-1501

High Fidelity Digital Image Compression Iterated Systems, Inc. 5550-A Peachtree Pkwy, Ste 650 Norcross, GA 30092 [small for profit] Stephen Demko 404-840-0633 770-840-0633
Development of Cost-Effective Routes to Compatibilize Polymers in a Commingled Waste Stream Michigan Molecular Institute 1910 W. St. Andrews Rd. Midland, MI 48640 [independent research organization] Conrad Balazs 517-832-5590

Synthesis and Processing of Nanocrystalline Ceramics on a Commercial Scale Nanophase Technologies Corp. 8205 So. Cass Ave., Ste 105 Darien, IL 60559 [small for profit] John Parker 708-323-1200
Research Joint Ventures (JV)
Development of Advanced Technologies and Systems for Controlling Dimensional Variation in Automobile Body Manufacturing. (Auto Body Consortium, JV with ASC, Inc., CDI Transportation Group, Inc., Classic Design, Delta Engineering, Detroit Center Tool, Inc., Efficient Engineering, Perception, Pioneer Engineering, Progressive Tool & Industries Co., Richard & Trute Tool & Die, General Motors, Chrysler, and the University of Michigan.) Auto Body Consotium 2901 Hubbard Ann Arbor, MI 48105-2467 [non profit] Ernie Vahala 313-741-5905

Hybrid Superconducting Digital System (Conductus, Inc., JV with TRW Inc., Hewlett-Packard, Stanford U., U.C. Berkeley) Conductus Inc. 969 West Maude Ave. Sunnyvale, CA 94086 [small for profit] John Rowell 408-523-9408
Cyclic Thermoplastic Liquid Composite Molding for Automotive Structures (Ford Motor Co. JV with General Electric) Ford Motor Co. Scientific Research Lab M/S 3182, PO Box 2053 Dearborn, MI 48121-2053 [large for profit] Carl Johnson 313-323-0399

Neural Network Control and Sensors for Complex Materials (Honeywell JV with Hercules Aerospace, Sheldahl, 3M) Honeywell 3660 Technology Dr. Minneapolis, MN 55418 [large for profit] Thomas Edman 612-951-7514
Scalable High-Density Electronics Based on MultiFilm Modules (The American Scaled-Electronics Consortium JV with the Microelectronics and Computer Technology Corporation, and its member companies) Kopin Corp. 695 Myles Standish Blvd. Taunton, MA 02780 [small for profit] Glenn Kephart 508-824-6696

NCMS Rapid Response Manufacturing (NCMS JV with Aries Technology, Cimflex Teknowledge Corp., Cimplex Corp., Dept. of Energy Oak Ridge Y-12 Facility, Ford, GM, ICAD, Parametric Technology Corp., Spatial Technology, Texas Instruments, and United Technologies.) National Center for Manufacturing Sciences (NCMS) 3025 Boardwalk Ann Arbor, MI 48108 [non profit] Bill Waddell 313-995-4903
Ultra-High Density Magnetic Recording Heads (NSIC JV with Applied Magnetics Corp., Digital Equipment Co., Eastman Kodak Company, Hewlett-Packard Corp., IBM, Quantum Corp., Storage Technology Corp., Carnegie Mellon University, University of Alabama, University of California at San Diego, University of Minnesota, and Wasington University.) National Storage Industry Consortium. (NSIC) 9888 Carroll Center Road San Diego, CA 92126 [non profit] John L. Simonds 619-578-2436

PREAMP - Pre-Competitive Advanced Manufacturing of Electrical Products (SCRA JV with Boeing, Digital Equipment Corp., Hewlett-Packard, GM/Hughes, Martin Marietta, Arthur D. Little, Battelle, and Mentor Graphics.) South Carolina Research Authority (SCRA) 5300 International Boulevard No. Charleston, SC 29418 [non profit] Jack Corley 803-760-3792
Monolithic Multiwavelength Laser Diode Array Spanning 430 to 1100nm (Spectra Diode Laboratories JV with Xerox Corp.) Spectra Diode Laboratories, Inc. 80 Rose Orchard Way San Jose, CA 95134-1356 [small for profit] David Welch, VP, Business Development 408-943-9411

Plasma Technology for Low-Cost Diamond Production

(Westinghouse Electric Corp. JV with SGS Tool Co.)

Westinghouse Electric Corp.
1310 Beulah Road
Pittsburgh, PA 15235-5098

[large for profit]

Dr. Howard Saunders
412-256-1960

APPENDIX 3: ABSTRACT

Proposed for NIST Publication (cite fully): Acceleration of Technology Development by the Advanced Technology Program: The Experience of 28 Projects Funded in 1991

Abstract: One of ATP's legislated mandates is to accelerate industry's commercialization of new technologies. Earlier surveys found that a majority of program participants believed that participation in the ATP had helped them to do just that – but the earlier surveys which addressed a variety of performance metrics did not provide details on why cycle-time reduction is of special importance to the companies, or on how participation in the ATP helped them to reduce their applied research and technology development cycle time and get to market more quickly, or on whether there were any effects beyond the ATP project. This survey, conducted via structured telephone interviews estimated that participating in ATP had helped them to reduce their technology development cycle time anywhere from 30% to 66% with the median response being a 50% reduction (most typically from a projected six-year cycle down to a three-year cycle). A little over half of the interviewees provided quantitative estimates of the economic value of reducing cycle time by a single year – the estimates ranged from $1 million to several billion, with a median average value of $5.5 million. They expected the positive impact on cycle time experienced in the applied-research stage to flow through to later stages in the technology development cycle (the product development, production, and marketing stages), thereby causing them to enter the marketplace more quickly. These cycle-time improvements were said to carry over to other technology development projects outside of ATP. Interviewees spoke of adapting specific "ATP practices" to related projects; applying methodologies and processes used or developed in the ATP project to the firm as a whole; developing a cultural bias favoring speedier processes; and taking advantage of the positioning provided by the enabling technologies developed in their ATP projects to accelerate the development of a whole series of related applications.

Key Words: acceleration of technology, applied research, cycle-time reduction, economic evaluation, impact analysis, performance metrics, program evaluation, research and development, technology transition.