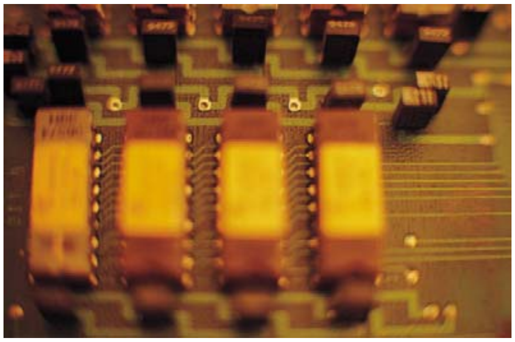

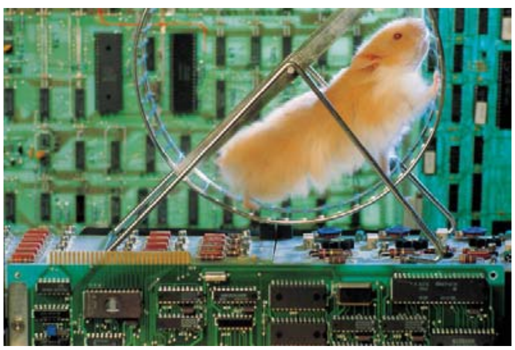

Impact Assessment of the Advanced Technology Program

Final Report

Prepared for:

Advisory Committee on Research Programs
Texas Higher Education Coordinating Board

By the:

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March 2005

"I never perfected an invention that I did not think about in terms of the service it might give others... I find out what the world needs, then I proceed to invent."

Thomas Alva Edison: Inventing the Electric Age
by Gene Adair, Oxford University Press 1996.

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Executive Summary

PURPOSE OF THE IMPACT ASSESSMENT

The purpose of this impact assessment was to:

> …carry out a longitudinal study of the impact of specific ARP/ATP funded projects to document long-term benefits and long-term impact of ARP/ATP funded research programs to both the educational and industrial enterprises in Texas. Data on successful translation of ATP results to commercialization should be collected. These data should document new major industrial programs that originated from ATP projects, new companies that were spun off, and new jobs that were created.[1]

This assessment addressed only the Advanced Technology Program (ATP), including the Technology Development and Transfer (TDT) grants, and not the Advanced Research Program (ARP). The assessment design was selected through the same competitive review process that determines all ATP awards.

When initiated in 1987 as part of a larger state strategy to diversify the State of Texas' economy, the Advanced Technology Program's goals, according to the originating legislation, were to "…conduct applied research …[that] will enhance the state's economic growth by: (1) educating the state's scientists and engineers; (2) creating new products and production processes; and (3) contributing to the application of science and technology to state businesses."

RESEARCH DESIGN METHODOLOGY

To ascertain the progress toward achieving the program's goals, a data-intensive research design was developed to: (1) determine the extent to which ATP has attracted the best students, educated scientists and engineers, and provided new entrepreneurs; (2) analyze the technology transfer and commercialization activities affecting ATP and compare them with best practices; (3) identify examples of the application of science and technology to state businesses; (4) compile economic impacts and economic benefits to date; and, (5) prepare policy recommendations for possible enhancements to ATP.

The assessment was based on an extensive range of primary and secondary information sources. Three major phases or series of tasks were undertaken to collect and analyze data for the 1,854 ATP/TDT projects funded in the biennial cycles from 1987 through

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[1] See *Advanced Research Program/Advanced Technology Program 2003 Program Announcements*, p, 4. Quoted material appeared originally in *Evaluation of the Advanced Research and Advanced Technology Programs: A Report of the Texas Higher Education Coordinating Board*, Mildred Dresselhaus, C. Robert Hewes, and Jiri Jonas, January 2003.

2001 (i.e., 1987, 1989, 1991, 1993, 1995, 1997, 1999, and 2001).[2] The aggregate grant funds dispensed has been approximately $320 million. If reasonable fringe benefit rates (20 percent) and indirect cost rates (50 percent) are included, the aggregate costs of all projects would increase to about $556 million.

Phase I was comprised of four data collection efforts: (1) a review of existing ATP database elements previously provided by principal investigators (PIs) in their reports to the Higher Education Coordinating Board; (2) an online survey of principal investigators covering more than 680 projects; (3) interviews with more than 100 TDT principal investigators; and (4) interviews with more than 100 ATP principal investigators.

Phase II focused on qualitative data collection leading to findings about technology commercialization; the impacts on students, scientists, engineers; and the educational process. Phase II was comprised of three data collection activities: (1) development of case studies on 31 projects that described the research and development, commercialization, and actual and potential future impacts; (2) interviews with commercialization stakeholders (i.e., university officials throughout Texas who have responsibilities for commercialization of university research and development, representatives from venture capital companies, and others) about the problems of and barriers to effective commercialization; and (3) interviews with businesses (industrial partners and CEOs of small technology companies) to determine their knowledge about, and experiences with, ATP/TDT and to solicit their views for making the programs more beneficial to their enterprises.

Phase III compiled information on student impacts and involved three benchmarking analyses. Student impact data were collected about the ATP with regard to recruitment of graduate students, industry involvement in educational processes, and employment in established and start-up companies upon graduation. Benchmarking examined (1) trends in the science and technology workforce for the State of Texas compared with other states; (2) aggregate research and development (R&D) outcomes for the State of Texas and select institutions, compared to other states and institutions nationally; and (3) outcomes from the Texas ATP compared to those of other institutions nationally, a national program, and other states' R&D programs.

The impact assessment should not be construed as an audit insofar as its preparation was not meant to conform to generally-accepted auditing principles and practices. Because of time and resource constraints entailed by the goals of the study, an on-site examination of documents was not made at universities nor was such information requested from university offices. Information was requested from start-up companies and partners that to some extent were proprietary. A majority of companies did not provide requested data, which prevented a systematic compilation of several key data elements such as sales revenues, real estate occupied, and tax revenues for individual governmental units.

Interviews with knowledgeable individuals, corporate partners, venture capitalists, and

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[2] Projects generally have been funded at between $160,000 and $220,000 for direct costs. The 2003 projects were not included in the impact assessment as that research and development has yet to conclude.

small business executives were conducted with the promise that their specific comments would remain anonymous and only be reported *en masse*. Although some quotes have been extracted to illustrate specific points, the large majority of comments remain confidential to honor the promise of anonymity. Comments made by PIs in response to survey questions concerning possible improvements in the ATP, also were treated as confidential, and university affiliations were deleted from most quotations.

Throughout the data collection process, the research team relied primarily on self-reporting, with vigorous double-checking in every instance of any data element that was a significant outlier to the majority of other respondents. Any errors in findings are likely to understate the ATP program impacts. Results and impacts should be viewed as conservative.

MAJOR QUANTIFIABLE ECONOMIC IMPACTS

The ATP/TDT awards, according to principal investigators (PIs), enhance their credibility with other sponsors and enable them more easily to secure follow-on research funding. Many subsequent grant awards are substantial. Dozens of PIs reported that their ATP/TDT awards led to subsequent research awards exceeding $1 million. One ATP PI noted that his award, along with that of another ATP awardee and two other colleagues, led directly to a $30 million foundation grant. Based on the survey results, follow-on funding for all ATP/TDT projects is estimated at $867.6 million. The large majority of this total has been secured from federal departments and agencies and is new research money for the State of Texas.

Licensing royalty revenues returned to Texas universities from all ATP/TDT projects are estimated at $38.6 million. Approximately 300 licenses have been issued as a result of ATP/TDT projects, with slightly more than 125 returning royalty payments. As is the pattern nationally, a small number of licenses provide a high proportion of the revenues.

Approximately 80 new companies have been formed around ATP/TDT technologies. Of these, approximately two-thirds remain operational. Sixteen of the companies have been acquired or merged into other entities. In the case of seven of the companies, for which market-based acquisition prices are public knowledge, the combined acquisition price totaled $184.1 million.[3] Several other potentially large transactions could not be determined due to their complexity, insufficient historical information, or other reasons.

Current full-time employment, at a minimum, for active start-up companies for 2004 is estimated at 156-169, with a minimum current annual salary from $10.1 to $12.7 million.[4] For a variety of reasons, a more reasonable annual estimate would be

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[3] Market-certified values and economic impacts, whenever possible, are used in this report. To obtain an overall assessment of program impacts, however, researcher-developed estimates, with appropriate limitations and cautions, are included as well.

[4] These figures do not include amounts from some acquired companies, companies that are inactive, or current companies that are located out-of-state and are partially attributable to ATP/TDT. These limitations

approximately double that range or between $20.2 million and $25.4 million. Based on a review of start-up company histories for all active companies, a reasonable five-year estimate of salaries falls between $101 and $127 million.[5]

Start-up companies have raised a minimum of $100.4 million from private investors and obtained an additional $6.7 million from government contracts. These estimates are conservative and do not include any amounts from start-up companies that were acquired and whose parent companies have subsequently raised funds.

Benefits enjoyed by industrial partners are estimated conservatively at $127.5 million, excluding dozens of projects cited by PIs for which economic benefits were unknown due to proprietary information or for benefits which could not be calculated. This figure also does not include operating efficiencies for partners who built new plants and only a token amount of actual capital expenditures.

Estimates were developed for post-project employment and salary impacts of students who have graduated. Using survey data and reasonable assumptions for salary levels and employment tenure, a minimum post-project salary total was calculated to be $112.6 million. Based on national employment tenure figures for post-graduation employment, the salary total was calculated to be $516 million. The lower figure was used in this assessment. Under either set of assumptions, post-employment salary impacts have been significant.

The total identifiable economic impacts are estimated as

Follow-on funding	$ 867.6 million
License and royalty revenue	38.6 million
Acquisition of start-ups	184.1 million
Start-up salaries (5 years)	101.0 million
Start-up capital raised	107.1 million
Partner economic benefits	127.5 million
Post-project student employment salaries	112.6 million
Total:	$1,538.5 million

Total identifiable economic impacts represent an approximately 5:1 return on the $320 million state investment in the ATP/TDT projects since their inception. If the higher student employment salary total, or many other estimates based on less reliable data were

could be substantial as two acquired companies had at least 40 employees each for a minimum of three years.

5 Estimates for additional years also were developed, but data were less precise. For this reason the longer estimates are not included.

incorporated, then the return certainly would exceed 6:1.

CASE STUDIES

To provide in-depth and qualitative information regarding ATP/TDT project outcomes, 31 case studies were developed. The case studies represent economic achievements, entrepreneurial successes, and technical and scientific innovation, and have been grouped by type of impact: (1) major follow-on funding, (2) new company formation, (3) promising commercialization opportunities, (4) partnerships, (5) significant student impact, and (6) licensing revenue. Each case contains an overview of the project, background on the research question, a description of the research process, a summary of the technology transfer/commercialization results, and additional comments. All of the cases exhibit some form of significant impact on the state's economy, and many offer more than one example of economic benefit to the state. Some cases contain suggestions for improving the ATP/TDT program.

STUDENT AND EDUCATIONAL IMPACTS

Educational impacts from ATP/TDT grants were examined under five specific topics:

- recruitment of talented undergraduate and graduate students to Texas universities;
- recruitment of talented faculty to Texas universities;
- student acquisition of new, marketable skills that make a positive contribution to the science and engineering workforce in Texas;
- retention of talented graduates (undergraduate and graduate degrees) within Texas, including the development of research positions in PI-generated startups; and
- faculty-student interaction with on-campus programs promoting entrepreneurial activities and strengthening the educational process.

Data collected unequivocally indicate that ATP/TDT programs create significant positive impacts in all five categories.

Sixty-three percent of PIs who responded reported that the programs were "very important" in attracting outstanding graduate students to their institutions, and 86 percent believed the programs were at least “moderately important.”

Forty-eight percent of PIs who responded reported that the programs were “very important” in attracting outstanding faculty, and 78 percent felt the programs were at least “moderately important.”

The total number of graduate students who participated in ATP/TDT projects was estimated at between 7,900 and 11,100; the number of undergraduates, between 3,300 and 4,500.[6] Principal investigators cited an extensive list of marketable, technical skills and competencies acquired by students who worked on their projects. Furthermore, by extrapolating survey responses to all projects, it is estimated that approximately 2,400 graduate students and 1,400 undergraduates worked in Texas after their ATP/TDT projects, which is equivalent to approximately two students per project. Therefore, the ATP/TDT program is helping to retain talented graduate and undergraduate students within the State of Texas after graduation.

In summary, the ATP program has generated significant student and educational benefits, which in turn has led to major benefits for employers within Texas.

BENCHMARKING SCIENCE AND TECHNOLOGY WORKFORCES

A central goal of the ATP program has been to strengthen the state's scientific and technological workforce by increasing the supply of engineers and scientifically trained graduates. It is important to note, however, that aggregate data across states cannot pinpoint the value of the ATP/TDT program because total research expenditures comprise less than 2 percent of total research and development expenditures in the State of Texas. Therefore, any major positive or negative changes in workforce characteristics are unlikely to be attributable to the program--the program is too small to have made a substantial difference one way or the other.[7]

One set of benchmarks compared the science and technology workforce in the state of Texas with that of thirteen other states, on a variety of human resource indicators. Both point-in-time and across-time comparisons were made based on data availability. It was found that the state's science and engineering workforce has developed very slowly in the past ten to fifteen years. Comparisons with other states reveal that, on many indicators, Texas still ranks far below the group of national leaders that includes California, New York, Massachusetts, Minnesota, and Maryland.

BENCHMARKING RESEARCH AND DEVELOPMENT EXPENDITURES – STATES AND INSTITUTIONS

Benchmarking data on research and development expenditures were compiled for Texas against a group of other states. Comparisons were made across states at a particular point in time as well as across time (1992-2002 and 1982-2002 for some others). Then institutional-level data were compiled for several public universities and health-related institutions within Texas. A final section examined health-institution data over time. Together, this composite of benchmarks provided a context within which ATP research and development is conducted.

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[6] PIs were given ranges from which to choose, and these are the likely medium and upper bounds.

[7] This set of benchmarks was performed to provide a general overview nationwide. Positive workforce impacts were determined through other methods.

In general, as a state, Texas compared unfavorably to other states. With the point-in-time comparisons, Texas ranked lower than most peer states on five research and development measures, as well as ranking below the national average on five measures. Only in terms of patents did Texas rank higher than many of the peer states and higher than the national average. The pattern was mixed in the six across-time comparisons. Texas ranked moderately well on two measures (i.e., patents and proportion of total R&D nationally) and improved on one measure (i.e., proportion of federal R&D funding). With the measures of industry R&D expenditures as a proportion of gross state product (GSP), and total R&D expenditures as a percentage of GSP, however, Texas ranked low throughout the time period. On the remaining measure (i.e., university R&D expenditures as a proportion of GSP), the state's ranking declined.

The institutional benchmark comparisons for the Texas health institutions showed a very positive result. The proportion of federal R&D funding captured by major Texas health institutions has increased over the past 20 years due to strong performances by several major health institutions. A similarly positive trend was found with the proportion of academic R&D funding garnered by major Texas health institutions. Not only has the combined proportion improved considerably, the rate of improvement was approximately ten times faster than one would expect due to population growth.

BENCHMARKING ATP/TDT PROGRAM OUTCOMES

ATP/TDT outcomes were benchmarked against a limited number of organizations and programs, none of which is exactly comparable to ATP, including:

- Association of University Technology Managers data for U.S. universities, U.S. hospitals, and Canadian universities;
- A subset of nine U.S. federal laboratories, with more extensive data for Oak Ridge National Lab, Lawrence Berkeley National Lab, and Lawrence Livermore National Lab;
- Georgia Research Alliance;
- Federal Advanced Technology Program; and
- Oklahoma Applied Research Program (OARS).

The expectation is that outcome metrics for research grant programs that fund applied research, such as Texas ATP/TDT, should be higher than for U.S. universities and Canadian institutions in general. Research expenditures for U.S. university research and development would support not only physical science disciplines but the social sciences and humanities, both of which are less likely to lead to intellectual property and the formation of new companies. Outcome data for U.S. hospitals and research institutes also should be somewhat lower than Texas ATP/TDT because their expenditures would include basic science expenditures. Federal laboratory metrics also should be lower than ATP/TDT outcomes for a number of reasons.

Actual findings generally confirmed expectations, although the degree of difference in some cases was greater than anticipated. Texas ATP/TDT metrics indeed were found to be superior to the general university population in the United States and Canada and the U.S. health and research institutes. In many cases, Texas ATP/TDT metrics were found to be far superior.

With other programs--for example, OARS and the federal ATP—outcome metrics were anticipated to be higher than the Texas ATP/TDT because both programs provide funding to private companies.[8] Research and development funding provided to companies is normally further downstream, more product-oriented, less risky, and more likely to result in commercialization outcomes than university research and development. In fact, the actual findings are somewhat mixed. In some instances, Texas ATP/TDT had lower metrics as expected, although in other cases its metrics exceeded those of other programs. The Texas ATP demonstrated no substantial deficiencies on any metric compared to other reasonably similar programs, however.

All program benchmark comparisons, it must be emphasized, suffer from severe data limitations. Inferences between Texas ATP/TDT and any other specific organization or program should be very carefully and cautiously drawn due to inherent differences in program objectives, award size and structure, and limited available data.

POTENTIAL CHANGES AND MODIFICATIONS

Based on review and analysis of collected information, the ATP program is fulfilling the original legislative goals, and its economic impacts are ongoing. No strong imperative exists for changing the ATP/TDT program. Nevertheless, should policymakers desire to enhance benefits in future years, the following possible modifications may be considered. The first set of recommendations can be undertaken with current program resources.

Proposal Review Process

Proposal Review Criteria—If enhanced commercialization is desired for TDT, the importance of the technology development and transfer plan should be increased, PIs' prior commercialization achievements should be upgraded, student involvement should be downgraded, and criterion about the likely economic benefits to the State of Texas should be considered.

Evaluators—Particularly with TDT proposals, consideration should be given to having experts in commercialization review two sections of all proposals: (a) product, process, service and (b) technology development and transfer.

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[8] Approximately 30 percent of OARS awards, with a higher proportion in recent years, have been made directly to private companies since the program inception. Federal ATP awards are conducted by private companies with only limited indirect university involvement Universities may participate but not lead in a joint venture. Since the beginning of the federal ATP, less than 10 percent of the total funding has been awarded to universities.

Coordinating Board/Advisory Committee on Research Programs

Goals for Future Commercialization—Goals should be established on key outcome metrics to reinforce systematically the commercialization objective for ATP/TDT.

Reporting Requirements—To ensure that program impacts are not underestimated because of insufficient information, future reporting should include more detailed information from PIs about start-up companies, from industrial partners about cost savings, process improvements, and product enhancements, and from students, to determine more precisely the role of projects in aiding them in employment and career decisions.

Post-Project Initiatives

Fundamental Information on Commercialization and Technology Transfer—Information should be offered to all successful award applicants about commercialization principles and fundamentals of effective technology transfer.

Supplemental Information For Commercialization—On a pilot project basis, commercialization support and guidance may be offered selectively to certain projects during the late stages of the research. Support could include direct assistance in creating business plans, developing marketing strategies, and brokering relationships for start-up company management. Also, a one- or two-day seminar on various topics of commercialization should be developed for all PIs, and several sessions should be led by PIs who can describe their experiences with particular commercialization barriers.

New Program Initiatives

Should new resources be allocated to the ATP program, filling existing gaps in commercialization processes may be addressed.

Prototype Funding—A new small grant program could provide resources solely for prototype development.

Large Grant Category—As a component of the normal grant cycle, a very limited number of larger grants, up to a maximum of $500,000 or $750,000, could be awarded to entice more experienced PIs and industrial partners to apply.

Internships and People Transfer Programs—To expose graduate students and some PIs to private sector R&D environments, a limited number of internships and semester-off programs could be supported.

Awareness and Knowledge of ATP/TDT—The ATP/TDT enjoys a considerable reputation with Texas scientists and university offices of sponsored research. Yet it is largely unrecognized by venture capitalists and other stakeholders. Raising awareness of the ATP/TDT may be accomplished through dedication of resources to outreach and information to new audiences.

THE ATP/TDT PROGRAM MISSION

The potential changes and modifications cited above will maintain the overall integrity of the ATP/TDT program while sharpening its focus to improve commercialization further in coming years. If a reconsideration of policy leads to the conclusion that near-term, direct economic outcomes are the overriding goal, then different approaches (product development or R&D grants to businesses) should be established.

Based on 1,854 ATP/TDT projects, on average:

- 1 project in 3 will yield a patent application
- 1 project in 3 will lead to some type of commercialization
- 1 project in 5 will lead to an issued patent
- 1 project in 6 will lead to a license
- 1 project in 22 will result in formation of a new company
- Excluding in-kind matching, each project will receive follow-on research funds of nearly three times the ATP grant
- Each project will provide paid positions to five graduate and two undergraduate students, and each project will lead to two new employees for Texas businesses.

In summary, the ATP/TDT program is fulfilling the original legislative goals, and its impacts to date have far surpassed the state’s investments.

Chapter 1: Introduction: Scope, Methodologies, and Limitations

PURPOSE OF THE IMPACT ASSESSMENT

In October 2002, the Texas Higher Education Coordinating Board, as required biennially by its enabling legislation, undertook an external expert evaluation of the Advanced Research and Advanced Technology Programs.[9] One of the recommendations from that evaluation was to carry out a longitudinal study that more fully assessed the impact of those programs.

Pursuant to that recommendation, as described in the 2003 Program Announcements for the Advanced Research Program and Advanced Technology Program, the purpose of the impact assessment was to

> …carry out a longitudinal study of the impact of specific ARP/ATP funded projects to document long-term benefits and long-term impact of ARP/ATP funded research programs to both the educational and industrial enterprises in Texas. Data on successful translation of ATP results to commercialization should be collected. These data should document new major industrial programs that originated from ATP projects, new companies that were spun off, and new jobs that were created.[10]

The assessment was obligated to address only the Advanced Technology Program grants, including the Technology Development and Transfer grants, and not the Advanced Research Program.[11] The assessment design was selected through the same competitive review process that determines all ATP awards. In accordance with the program announcement, the ATP impact study was to transpire over a 14-month period beginning January 2004. The grantee was to be required to file a preliminary report in December 2004, to submit a progress report, and to deliver a final report by March 1, 2005. As part of the grant conditions determined subsequent to the award, the principal investigator presented status reports to the quarterly meetings of the Advisory Committee on Research Programs of the State of Texas Higher Education Coordinating Board.

When initiated in 1987 as part of a larger state strategy to diversify the State of Texas' economy, the Advanced Technology Program (ATP) and Advanced Research Program (ARP) were the most ambitious technology efforts ever undertaken with the talent and resources from a state's research universities. According to the originating legislation,

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9 http://www.arpatp.com/archive/pdf/0076.pdf

10 See *Advanced Research Program/Advanced Technology Program 2003 Program Announcements*, page four. Quoted material appeared originally in *Evaluation of the Advanced Research and Advanced Technology Programs: A Report of the Texas Higher Education Coordinating Board*, Mildred Dresselhaus, C. Robert Hewes, and Jiri Jonas, January 2003.

11 Throughout this assessment report the Advanced Technology Program (ATP) should be interpreted to include TDT as well, unless otherwise noted.

ATP's goals were to "…conduct applied research …[that] will enhance the state's economic growth by: (1) educating the state's scientists and engineers; (2) creating new products and production processes; and (3) contributing to the application of science and technology to state businesses."

RESEARCH DESIGN METHODOLOGY

To determine what progress has occurred in achieving the program's goals, a data-intensive research design was developed to: (1) determine the extent to which ATP has attracted the best students, educated scientists and engineers, and fostered new entrepreneurs; (2) analyze the technology transfer and commercialization activities affecting ATP and compare them with best practices; (3) identify examples of the application of science and technology to state businesses; (4) compile economic impacts and economic benefits to date; and (5) prepare policy recommendations for possible enhancements to ATP.

The assessment was based on an extensive range of primary and secondary information sources. One major source was the database of proposals, interim reports, and final reports for all ATP/TDT projects provided by the research staff of the State of Texas Higher Education Coordinating Board. The bulk of information researched for the assessment, however, was newly collected data.

Three major phases or series of tasks were undertaken to collect and analyze data for the 1,854 ATP/TDT projects funded (totaling approximately $320 million) in the biennial cycles from 1987 through 2001 (i.e., 1987, 1989, 1991, 1993, 1995, 1997, 1999, and 2001).[12]

Phase I was comprised of four data collection efforts, as follows.

- *Review of Existing ATP Database Elements*

  A review of data files initiated prior to the project's formal start date.

- *Written Survey*

  All of the PIs in the ATP award database were provided the opportunity to share information about their project's results and opinions about the program through a written survey.

[12] With some exceptions, most awards have been two years in duration and begin in the calendar year after they are awarded, for example, projects selected in 1987 began in January 1988 and ended in December 1989. Projects generally have been funded at between $160,000 and $220,000 for direct costs. Fringe benefits and overhead (indirect costs) were not included in project budgets. The 2003 projects were not included in the impact assessment as that research and development has yet to be concluded.

- *Technology Development and Transfer (TDT) Telephone Survey and TDT Project Reviews*

  TDT projects began formally in 1993 as a subset of the ATP program (with slightly different conditions). Each of the 156 TDT projects funded from 1993 through 2001 was reviewed. Phone interviews were attempted with all TDT principal investigators (PIs).

- *ATP Telephone Survey and ATP Project Reviews*

  More than 120 phone interviews were conducted with ATP PIs, based on their responses to the survey. All academic and technology fields and all award cycles were included.[13]

The four data collection protocols in Phase I served as the initial basis for the collection of significant quantitative data about the commercialization of the research and about the economic impacts.[14]

Phase II focused on qualitative data collection leading to findings about technology commercialization, the impacts on students, scientists, engineers, and the educational process.

Phase II was comprised of three data collection activities, as follows.

- *Case Studies*

  Different types of projects were selected for in-depth analyses:

  (1) Projects whose outcomes have been limited or hindered by legal issues, as legal disputes arising from technology commercialization are neither rare nor trivial

  (2) Projects with outstanding commercialization experiences and,

  (3) Projects with promising opportunities at this time

  Some projects fell into two of these categories. A total of 31 cases were prepared that described the research and development, the results, if any, in terms of commercialization, and other actual and potential future impacts.

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13 Originally ATP PIs were to be randomly selected. Because the survey responses required follow-up to probe further about economic impacts and because of the difficulty in reaching PIs who had retired, moved, were deceased, or were unresponsive, the more focused set of ATP phone interviews was conducted.

14 The data collection procedures are described in more detail later in this assessment.

- *Interviews with Commercialization Partners*

  On-site interviews were conducted with university officials throughout Texas who have responsibilities for commercialization of university research and development. Interviews also were performed with representatives from venture capital companies, incubator directors, and others with extensive knowledge about commercialization of university research. These interviews concentrated on problems and barriers to effective commercialization (e.g., discipline-specific barriers) as well as characteristics essential for the commercialization process across all fields. Approximately 30 interviews were conducted.

- *Interviews with Businesses*

  A final set of interviews, with select corporate research staffs, CEOs of small technology companies, and partners, was conducted to determine their knowledge about, and experiences with, ATP, and to solicit their views for making ATP more useful to their enterprises.

Phase III compiled information on student impacts and involved three benchmarking analyses, as follows.

- *Students*

  Student impact data were collected regarding views about the ATP in recruitment of graduate students, industry involvement in educational processes, students as agents of technology transfer upon graduation, and employment in established and start-up companies.

- *Benchmarking*

  Three analyses were completed:

  (1) Trends in the science and technology workforce for the State of Texas were compared with those of leader and peer states

  (2) Aggregate research and development (R&D) outcomes for the State of Texas and select institutions were compared to other states and institutions nationally

(3) Outcomes from the Texas ATP were compared to those of institutions nationally, a national program, and other states' R&D programs.

The three benchmarking analyses provided contextual information as well as additional evidence of ATP impacts.

DATA COLLECTION LIMITATIONS

The impact assessment should not be construed as an audit insofar as it was not prepared under generally accepted auditing principles and practices. Due to time and resource constraints as well as the goals of the study, the assessment team did not attempt to examine financial or administrative records on site at universities which might have verified economic impacts such as follow-on research funding, patents, and licenses and license income. Nor did the team request such detailed information from those university offices (i.e., Technology Transfer and Licensing Offices and Sponsored Research Offices). The primary sources of information were the principal investigators, supplemented by extensive review procedures, including examination of project records submitted to the ATP research program staff at the Higher Education Coordinating Board.

Information was requested from start-up businesses and partners that to some extent was considered to be proprietary. The research team attempted to obtain such information using various methods intended to limit the specificity of the data, or that allowed companies to conceal confidential data. A minority of companies provided data based on these assurances. However, a systematic compilation of several key data elements such as total salaries of employees, sales revenues, real estate assets owned, and tax revenues for individual governmental units was impossible for the majority of companies. As with project and university-based data, the research team relied primarily on self-reporting, with vigorous double-checking of any data that was an outlier to the majority of other respondents.

Interviews with knowledgeable individuals, corporate partners, venture capitalists, and small business executives were conducted with the promise that their anonymity would be honored and their comments reported on *en masse.* While some quotes have been extracted to illustrate specific points, the majority are unattributed to honor the promise of anonymity. Comments made by PIs in response to survey questions concerning possible improvements in the ATP also were treated as confidential.

While there can be no guarantee that some unreliable data have been incorporated into the results, the likelihood that the basis for findings have been tainted by unreliable data is miniscule for three reasons. First, most PIs have little, if any, incentive to inflate the results of their projects. PIs were told clearly that data were being gathered to produce an overall profile of the ATP program as an entity and not to evaluate any individual projects. Second, because all major outlier data on the survey were re-confirmed by PIs, it is very unlikely that the remaining data are in error by any appreciable amount. Third, a large number of interpretive decisions were necessary throughout the impact assessment, for instance, allocating some type of economic impact (e.g., number of employees) to ATP and non-ATP R&D projects. Staff members have consistently maintained an objective approach and when doubt arose, any interpretation was deliberately made on the conservative side rather than over-generously allocating impacts. For all these reasons and others as noted in several chapters below, the ATP program impacts can be viewed as conservatively. Where error in findings may occur, it is highly unlikely to be overstatement.

REPORT OVERVIEW AND ORGANIZATION

This report has been prepared for different audiences in a "triage format," that is to say, key findings and recommendations appear in the executive summary, highlights at the beginning of each chapter, detailed materials are presented in individual chapters, and specialized materials may be found in the appendices. To the extent possible, technical language has been avoided, and graphics have been prepared to facilitate comprehension by policymakers, senior government officials, and business executives.

Chapter 2 describes the survey process, methodology, and key findings.

Chapter 3 provides the summaries of non-attributed interviews with principal investigators of TDT projects and ATP projects. The primary topics of those interviews were commercialization issues, economic impacts, and student impacts. A final section of chapter 3 also presents suggestions from PIs for improvements in the ATP program.

Chapter 4 presents the 31 case studies that are intended to portray the full breadth and potential of ATP/TDT projects. A number of the cases exemplify past entrepreneurial successes, while others illustrate significant potential, and others describe challenges in the commercialization of university research and development.

Chapter 5 contains summaries of non-attributed interviews with university officials, knowledgeable industry experts, key commercialization partners, and corporate research staffs. The focus is on technology commercialization, particularly potential improvements and changes, and possible changes in the ATP program itself.

Chapter 6 examines the effects of ATP/TDT projects on students and educational processes. It also contains an estimate of the employment impacts in Texas for graduates who worked on ATP/TDT projects.

Chapter 7 provides the three benchmarking analyses: science and technology workforce, research and development expenditures, and program comparisons. In each analysis, available data from published sources are used to compare Texas, select Texas universities, and the ATP program with appropriate states, institutions, and programs elsewhere.

Chapter 8 is devoted to new companies that have been formed as a result of ATP/TDT projects. An overall summary is provided along with profiles of several dozen companies.

Chapter 9 contains several discrete analyses: (1) technology transfer plans in a sample of TDT proposals; (2) other economic benefits; and (3) a breakdown of proposal review comments by principal investigators.

Chapter 10 presents potential changes and modifications to the ATP/TDT program.

Various appendices are provided subsequent to the main report.

ATP IMPACT ASSESSMENT RESEARCH STAFF

A team conducted the impact assessment. Dr. James Jarrett, Senior Research Scientist, the Bureau of Business Research, McCombs School of Business, of the University of Texas at Austin, served as the principal investigator. Robert Meyer served as the senior researcher and co-author of the assessment. Additional research and analyses were conducted by Mike Hayes, David Schieck, Dr. Elizabeth Durden, Ben Henning, Jiten Sanghai, JranDe Lee, Leah Campbell, Farah Rajan, Brianna Huntsberger, and Dr. Darius Mahdjoubi. Dr. Bruce Kellison performed research and administrative functions, and Dorothy Brady and Sally Furgeson served as the primary editors. The impact assessment was performed throughout calendar year 2004 and early 2005.

ACKNOWLEDGEMENTS

The research team wishes to thank the Advisory Committee on Research Programs (ACORP) of the Texas Higher Education Coordinating Board for their support and cooperation with this impact assessment. ACORP is led by Dr. Norman Hackerman, Chair, and Dr. Billy E. Welch, Vice Chair. Also, we wish to express our appreciation to the staff of the Texas Higher Education Coordinating Board for assistance during the project. Dr. Linda Domelsmith, Director of Research and the point of contact for the assessment, fielded numerous inquiries for information and always responded promptly. We wish to express our gratitude as well to Dr. Deborah Greene, Gala Peters, Dr. Cornelius Reinhold, and Dale Cherry for providing assistance and information throughout this project.

We are especially indebted to the principal investigators of ATP/TDT projects who so graciously provided information, insights, and perspectives about the program. Without their cooperation and involvement, this task would have been much more difficult.

We also wish to thank many anonymous individuals from universities, venture capital firms, industrial partners, start-up companies, and private corporations, who provided information in interviews and contributed their time and expertise to this assessment.

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Chapter 2: Findings from Written Survey

INTRODUCTION

Assessing the impact of the Advanced Technology and Technology Development and Transfer projects on the Texas economy involved thorough collection and analysis of information. The project's primary data collection instrument was a survey of all principal investigators who had received either an ATP or TDT grant during the period 1987-2001.

SURVEY SAMPLE

Out of a total of 1,215 principal investigators (PIs) who had won awards between 1987 and 2001, we were able to contact 1,056 by phone or e-mail. Communication with the remaining 159 PIs proved ineffective for a variety of reasons such as failed email addresses, retirements, and deaths. We asked all contacted PIs to complete an online survey hosted by a commercial vendor (SurveyPro.com). We asked the PIs who had received more than one award to complete the survey for each of their projects. A total of 506 PIs completed all or part of the survey, a 41.6 % response rate. About 20% of those responses were relatively minimal.

The survey responses, by research area, were representative of the entire universe of projects. A graphical depiction is shown in the Project Fields Distribution on the following page.[15] The responses by project type (ATP or TDT) are shown below:

ATP:	633 responses out of 1,698	(37.3%)
TDT:	50 responses out of 156	(32.1%)
Combined:	683 responses out of 1,854	(36.8%)

Therefore, the survey responses comprised approximately 37% of all projects funded between 1987 and 2001.

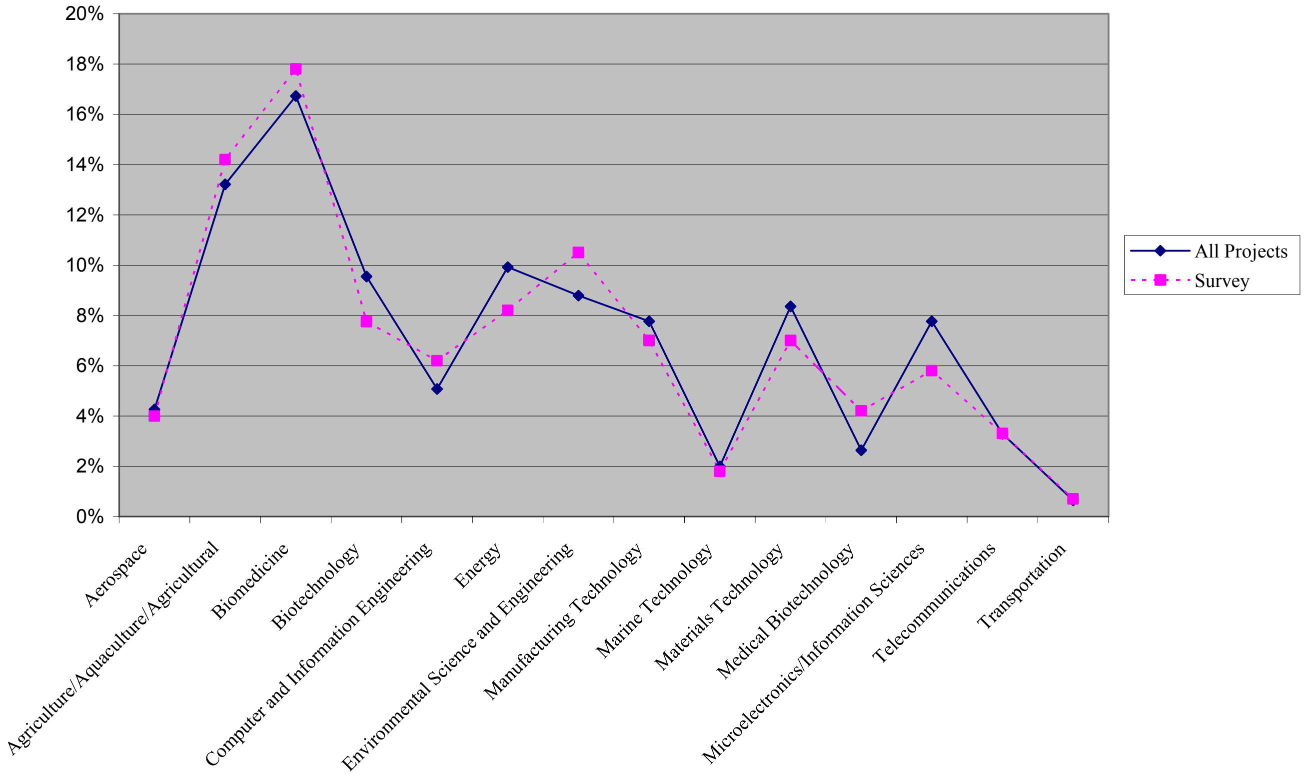
The survey responses were slightly different than some of the universe of projects on other characteristics, however, but only marginally. There were slightly more PIs among the respondents who received one award than in the universe of all projects (76.9% vs. 67%).[16] Also, a slightly lower percentage of PIs receiving TDT awards responded than that of the overall program award pool (7.3% vs. 8.4% overall). Finally, there were also more PIs with projects in post-1995 funding cycles among our respondents than in the

[15] A chi-square test of the 14 fields confirmed that the survey responses were representative of all projects. A second chi-square test of 10 fields, which combined several closely related fields, also was statistically significant in term of representativeness by research field.

[16] In other words, while two-thirds of PIs have received only one award, in the sample of responses, three-quarters of the PIs had received one award. This no doubt is due to our request that PIs provide information about each of their projects, which increased the reporting burden for those with multiple projects.

overall universe of projects, probably because these PIs were easier to reach, but also because they may have felt more comfortable discussing the details of more recently concluded projects.[17]

Project Fields Distribution



SURVEY DESIGN AND METHODOLOGY

The survey was designed to elicit significant quantities of information on the ATP and TDT programs' economic and workforce impacts in Texas, as well as the programs' various educational impacts, such as their utility in attracting and retaining outstanding students and faculty. The draft survey instrument, shown in its entirety in Appendix A, was pilot tested by a group of University of Texas at Austin ATP/TDT grant recipients. Based on feedback from these individuals, the survey was modified and finalized for widespread distribution.

[17] While none of these three is likely to skew appreciably the findings, the first two factors probably lead to slightly lower commercialization outcomes. TDT projects are a select group with high potential for commercialization, and PIs with multiple projects presumably have more experience and operate under favorable conditions that reviewers believed would lead to successful outcomes. It is unknown if the third factor would lead to any differences.

All principal investigators received an emailed letter of introduction to the impact study containing a hyperlink to the survey. (See Appendix B for a copy of the letter and follow-up letters.) Survey links were individualized to provide protection for reported data and to provide mechanisms for tracking respondents. Since the survey requested information specific to individual projects, the estimated completion time varied greatly by principal investigator, but was designed to take 15-25 minutes per project to finish.

After the initial letter of introduction, principal investigators who did not complete the survey within six weeks received two additional reminder email messages during that time. Reminder emails emphasized completion only of those portions of the survey for which information could be readily recalled (Sections A and C). Additional surveys were distributed as email attachments to principal investigators who wished to respond but could not do so via the Internet.

The survey instrument used a combination of multiple choice and open-ended questions. It was comprised of three distinct sections and a total of thirty-one questions. Because PI's already report regularly about their projects to the Higher Education Coordinating Board research staff, only five of the thirty-one questions were necessary to "complete" the survey.

We conducted preliminary data screening on a rolling basis as survey responses were received. An initial review of the results revealed several inconsistencies in survey responses, including data that appeared to have been entered multiple times, and several incomplete responses. We performed a systematic and careful manual screening of all responses as they were received. Over a period of months, additional screening and verification occurred for all major outlier data elements. The final database included both completed and partially completed survey responses.

MAJOR SURVEY FINDINGS

Section A of the survey solicited general information on award and project types. Section B, which comprised the bulk of the survey, requested project-specific information. Section C requested the principal investigators' general impressions of the ATP and TDT programs, and of the efficacy of these programs within the university and private-sector research framework.

Most detailed findings are described in separate chapters of this report. Select highlights are presented below. For several of the results, both the actual number from the survey and the derived number for all projects are presented. The conversion method is straightforward. Actual numbers are based solely on the responses to the survey, and the survey comprises approximately 36.8% of all ATP and TDT projects funded to date. Because the survey responses, as noted previously in this chapter, are representative of all projects, it is possible to project to the entire universe. For instance, invention disclosures from the survey totaled 300. To compute the estimated number of invention disclosures for *all projects,* not just those included in the survey responses, the survey value for invention disclosures (300) is multiplied by a factor of 2.72 (1 / 0.368 = 2.72). Therefore, the total number of invention disclosures for all projects, assuming a 100% PI response rate, is estimated at 816 (300 X 2.72 = 816). Similar calculations are made with the 2.72 factor for other responses as noted.

Students

Between 7,900 and 11,174 graduate students have worked on all ATP/TDT projects.
Between 3,307 and 4,540 undergraduate students have worked on all projects.

Commercialization Stages

At what stage of the technology or product development cycle is your project?

No product development is anticipated	40%
At least one more year of R&D is required	28%
Prototype process development is occurring now or has been developed	17%
The project is beyond the prototype stage	3%
Serious planning for commercialization is underway	4%
Commercialization has begun	7%

Impediments to Commercialization

Fewer than one in five (18%) principal investigators have encountered any problems or impediments with their collaborators or industry sponsors, with their university, that have prevented them from achieving the desired potential of their research. About one-quarter (24%) do not have any further funding needs towards achieving the desired commercial potential of their research. About one-third have need for further R&D funding, approximately one-fifth (19.8%) will need financial assistance, and about one-tenth will need either marketing assistance or manufacturing assistance.

Intellectual Property

	Actual Number	All Projects
Inventions disclosed	300	816
Patents filed	235	639
Patents issued	141	383
Products introduced to market	67	182
Copyrights registered	33	90
Non-funded collaborations with other academic or industry alliances	279	759
Licenses granted, total	113	307
Number of licenses granted to companies in which your university holds stock or otherwise has equity share	19	52
Number of licenses currently returning royalty or non-royalty payments	47	127
Number of licensees living or working in Texas	24	65
Total amount (dollars) of license gross revenue (total royalty and non-royalty payments) earned by project to date	$14.2 million	$ 38.6 million

Additional Research Funding

	Actual Number	All Projects
Follow-on federal research funding:	$196.2 million	$533.6 million
Follow-on industrial research funding:	54.6 million	148.5 million
Follow-on research funding from state, foundation, or international sources:	68.2 million	185.5 million
Total follow-on research funding (all sources)	$319.0 million	$867.6 million

Benefits to Companies

More than one-quarter (27%) of the projects have led to the adoption by an industry partner of a new process (or improvement of an existing process), or, produced cost savings, cost avoidance, or a product enhancement. The total benefit, estimated conservatively for the total universe of projects, was $127.5 million.

Survey respondents identified a total of 80 new major industrial programs. The estimated total for all ATP/TDT projects is approximately 217.

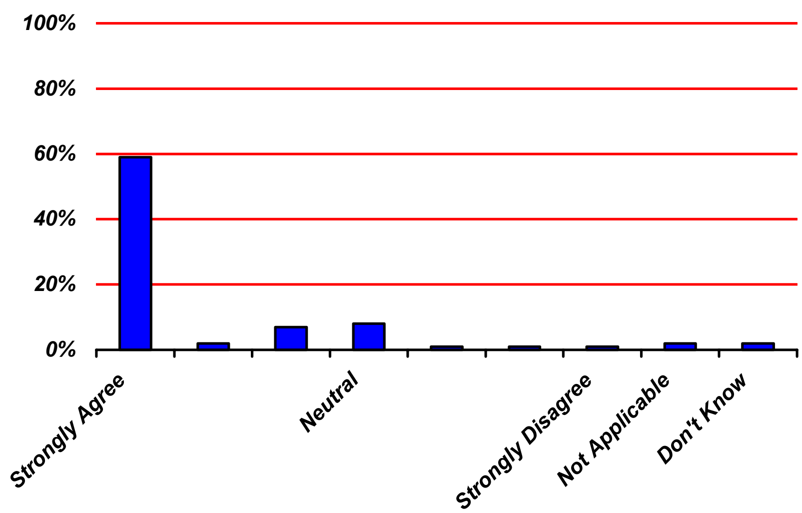
ATP/TDT projects enhance the credibility of principal investigators.

ATP/TDT project awards enhance the credibility of principal investigators as they pursue research funds from national, industrial, and foundation sponsors. This credibility leads to further research funding and additional economic benefits to the State of Texas.

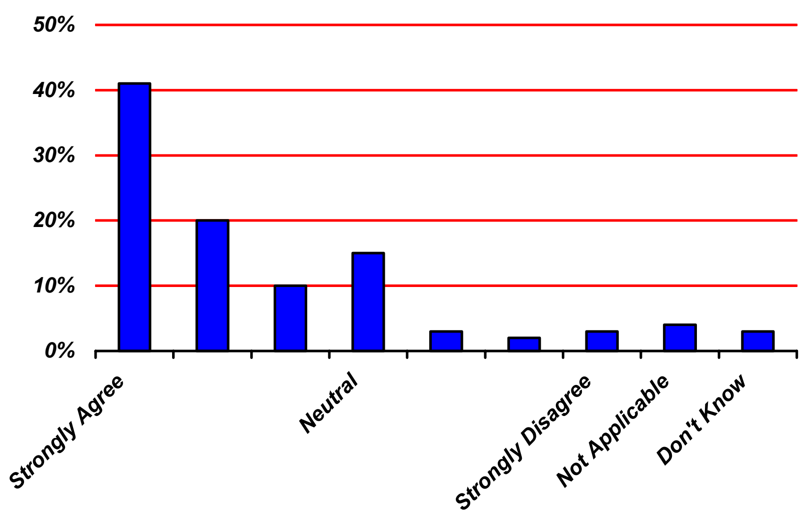
Responses to a series of questions are shown below. Principal investigators were asked:

"Indicate if you agree or disagree with the following statements."

The ATP/TDT award provided enhanced credibility for subsequent research application(s) to federal agencies, industrial sponsors, or investors.

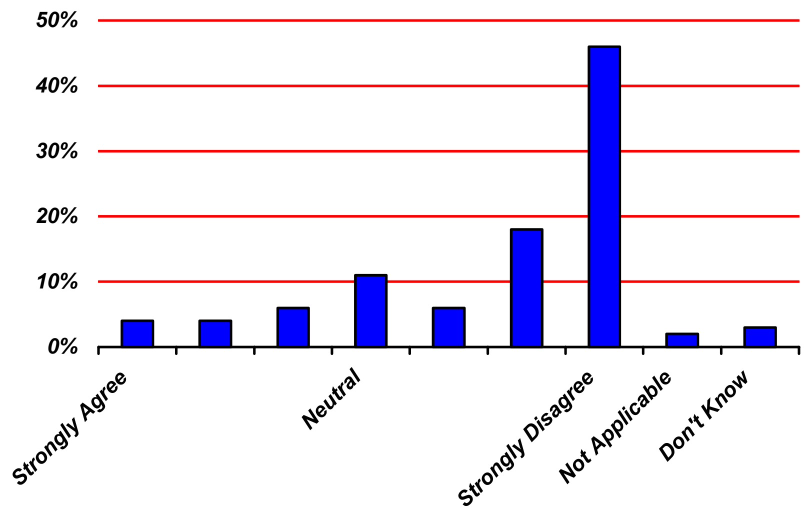


The ATP award enabled me to secure additional federal or foundation funding, which I likely would not have obtained otherwise.

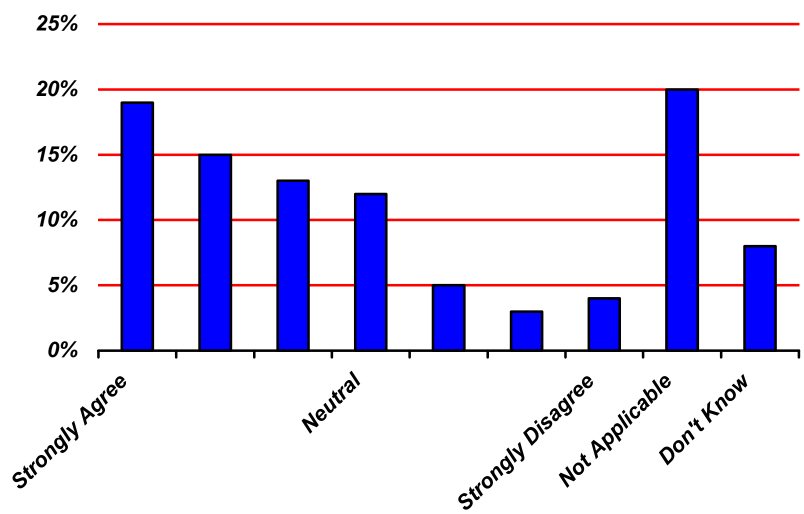


Commercialization would not have proceeded without ATP/TDT funding.

Without the ATP/TDT award, I would have pursued development of the technology at about the same level of effort and with the same ultimate goal.

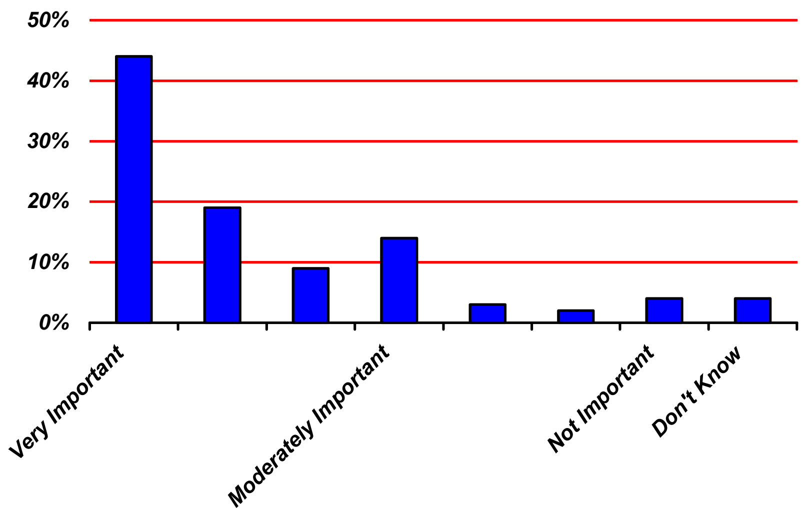


As a result of the funding received under the Advanced Technology Program the commercialization of technology was accelerated.

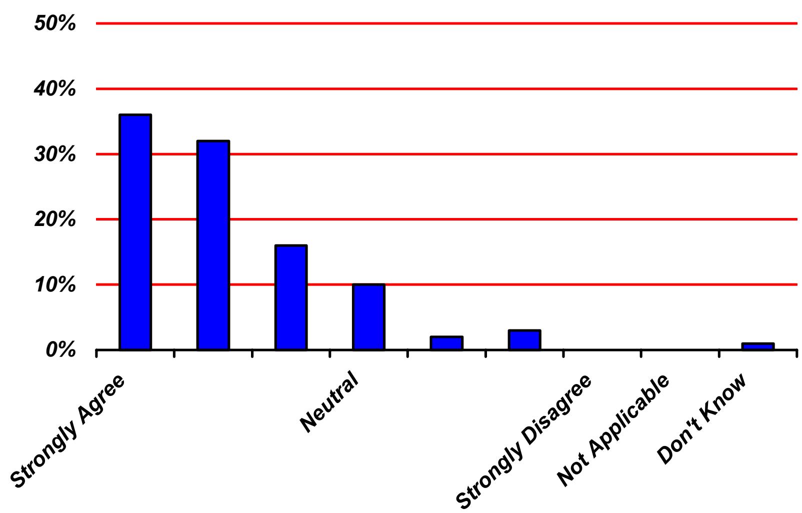


The ATP/TDT awards are important in attracting outstanding graduate students and perform a valuable role in educating students for job markets and career tracks.

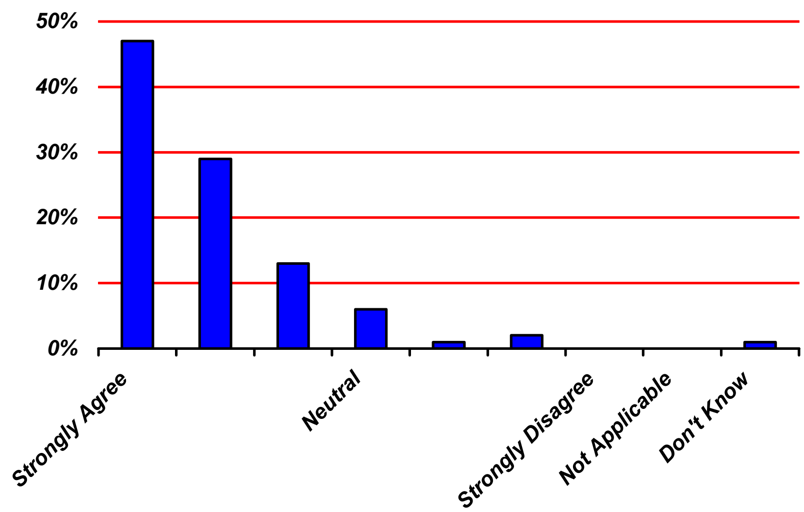
How important are the ATP/TDT grant programs in ATTRACTING outstanding *graduate* students to your institution?



Educated students are the most important product of the ATP/TDT programs.



ATP/TDT programs contribute significantly to producing graduates properly educated for their intended job markets and future career tracks.



Additional findings from the survey are described in more detail in subsequent chapters.

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Chapter 3: Summaries of Non-Attributed Interviews with Principal Investigators

3.1 TDT Findings

HIGHLIGHTS

- 90% of all PIs awarded TDT grants were interviewed.
- Rich financial and scientific rewards have been returned to the State of Texas as a consequence of the TDT Program.
- Returns from the program in the form of academic scholarship, the attraction of follow on funding, student employment and scientific achievement have been high.
- Intellectual property from a TDT project occasionally has been placed into the public domain.
- The TDT program has played a significant role in a large number of successful commercialization efforts.

INTRODUCTION

The results of the TDT Principal Investigator Interview Evaluation Phase are organized by the topics discussed during the interviews:

- Commercialization Results
- Ongoing Commercialization
- Thwarted Commercial Outcomes
- Technology Transfer
- Ongoing Research
- Additional Funding
- Personal and Career Rewards

In the history of the program, the Texas Higher Education Coordinating Board through its Review Panels has selected a total of 156 TDT proposals for awards to 135 principal investigators (PIs) of whom 122 were contacted and interviewed. After repeated failed attempts to initiate contact, the 34 PIs remained unresponsive.

Both qualitative and quantitative data derived from the interviews indicate a wide range of project results in every category of research. In some cases outstanding commercialization results have been achieved under circumstances where institutions enjoyed good financial return. As would be expected, however, some projects produced few if any significant benefits beyond incrementally adding to the body of scientific knowledge and supporting the University's mission of education, graduate training, and dissemination of knowledge through publication. Other projects attained very positive economic results for the public good in circumstances where no license was granted and no royalties were paid to the institutions owning the rights to the intellectual property. In a few instances intellectual property was either inadvertently or purposefully placed in the public domain. Many TDT projects concluded with the realization that further technical refinement was unavoidable. At the termination of TDT funding, many researchers with promising technologies found that further funding was necessary to refine the science one step further. Overall, strong relationships were frequently found between certain industrial partners and PIs undertaking sponsored research. Often, an industrial sponsor with a problem seeking a technical solution that held commercial promise would provide ongoing funding of a PI's further research

During interviews, PIs often expressed very strong positive sentiment about the benefits of the TDT Program. In no case was a PI critical of the Texas Higher Education Coordinating Board's mission or its execution on policy. In a few instances PIs highly praised the Board. The overwhelming impression gained from the interviews is that the TDT program is valuable, and in many instances key, to fostering research commercialization and commercial success.

COMMERCIALIZATION RESULTS

The TDT program has played a significant role in a number of successful commercialization efforts. Although in some cases a company may no longer be producing product because a technology has become obsolete and needs improvement, there has been a long history of successfully manufactured products that have earned licensing fees.[18] For example, a now dissolved company formerly operating as Respironics sublicensed to the then-largest sleep apnea manufacturer in the USA and possibly the first or second largest in the world. Substantial royalties were earned by the state and the co-inventors are now managing and earning royalties from the operation of a sleep lab.[19] Instruments that an industrial partner company developed were sold to Washington State University and to a federal agency.[20] In another case, a start-up company was formed, patent rights were licensed, and a product was sold in an industry historically very slow to respond to innovation.[21]

Many TDT grants funded research that was incremental to further scientific inquiry, though in some cases benchmark results may not have been attained. Although scientific success was achieved in many cases, there were a number of reasons for less than superior economic results. The technology could have still been in the exploratory stages.[22] More development of the technology could have been required while confidence remained high for more funding and collaboration.[23] Positive results may not

[18] 000512-0191-1995; 000512-0312-1999
[19] 003656-0122-1993; 003656-0105-1955
[20] 010366-0064-2001
[21] 000512-0294-2001
[22] 010366-0167-2001
[23] 003656-0006-2001

have been sufficiently robust and the technology may not have been product-ready.[24] In some cases even though a provisional patent was filed, no commercialization may have occurred with a technology that clearly would benefit human subjects because further development was needed.[25] A general economic slowdown occasionally stalled commercialization.[26] It may simply have been the case that no more funding was available.[27] Technology that could have been developed further may have been left sitting fallow for want of venture capital.[28] Many additional reasons were reported by principal investigators that contributed to the lack of commercialization, including a lack of definitive results (although the technology may have been better than the current industry capability), and resistance in an industry that was naturally reluctant to take risks on new technologies.[29]

ONGOING COMMERCIALIZATION

Many TDT projects are currently in the process of commercialization and offer strong promise of financial return and/or another step toward scientific justification. One technology represents a large step in environmental protection offering a high tech, systematic environmentally friendly service for recycling computers in what could have a large economic impact for Texas and the world.[30] Currently under construction is a large-scale pilot system targeted at cottonseed oil processing with wider applications for any type of crude oil.[31] A start-up opportunity is emerging for a PI who has high confidence that a technology can be efficiently scaled, a technical formulation can be implemented, and a pilot plant ultimately will be funded.[32] An International Technology Consortium is moving commercialization forward with venture capital funding and several Texas Universities to form a Texas subsidiary company founded on a high-tech motor drive IP portfolio financed partially with TDT funding.[33] Product will be brought to market soon along multiple commercialization paths with well-established large commercial partners.[34] In collaboration with two semi-conductor manufacturers, commercialization of a technology will have a significant impact on the US and the Texas semi-conductor industry by reducing the time requirements for testing by a couple of seconds.[35] Research projects funded by the TDT program through time unquestionably have far reaching economic impact that place Texas within, and frequently at the center of, an industry's financial and technical locus.

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[24] 003657-0055-1997
[25] 003604-0045-2001
[26] 000512-0312-1999
[27] 000517-0316-1999
[28] 000517-0231-1995
[29] 000512-0338-2001
[30] 003644-0263-1999
[31] 000512-0079-1997
[32] 003656-0154-2001
[33] 000512-0285-2001
[34] 000512-0435-1999
[35] 000512-0319-2001

THWARTED COMMERCIAL OUTCOMES

Commercialization of a technology may have occurred, but for a variety of reasons there was no financial return to the universities for the use of the patent rights. In one case after a PI could not accommodate technical limitations, a large aerospace firm began to produce nosecones whose design was incrementally improved by the technology.[36] A PI disclosed that a major corporation uses a technology in their plant after having sponsored research but never having licensed it.[37] The Texas economy benefited through the advancement in DNA markers for grain quality and disease-resistant genes perfected with a technology that was placed in the public domain and is freely available to public breeding labs.[38] A Texas Agricultural Experiment Station technology used globally was commercialized through the facilitation of a PI who had a colleague at a Dallas engineering firm that adopted the technology without a license.[39] A subsidiary of a major international corporation that sponsored the research originally is marketing a successful commercial software considered #1 in the market space and is based on an improved software the University has not licensed.[40] Following the failure of process patent protection for a technology credited with moving Texas from 3rd place to 2nd place in peanut production, a new start-up company, Crop Docs Inc., is being formed around an improved version of the technology with carefully prosecuted patent protection.[41] Although no license was issued a major corporation adopted a snack line production improvement technology internally in many of its plants.[42]

In some situations either a decision was made to place the intellectual property in the public domain or it occurred inadvertently. A PI deferred to the education mission of their university rather than to the goal of commercialization in making a decision to relieve a bottleneck in the timber industry by placing a superior technology into the public domain that is now commercialized in seven countries.[43] In another case, there is no licensing activity but a broadly used technology originally focused on marine animal isolates for which there was no substantial market has now entered the public domain.[44]

Not all interviewees reported experiences that were entirely positive. In the heat of development, controversy has erupted at times between a PI and a commercializing entity and/or with the university. In the face of what was reportedly a pattern of changed positions by the university, one founder/inventor broke off negotiations with the university and abandoned plans for a start-up company causing the technology to enter the public domain despite strong interest by major international corporations to

[36] 003652-0193-1999; 003652-0883-1997
[37] 000517-0125-1993
[38] 000517-0222-1993; 000517-0094-1995
[39] 000517-0223-1993
[40] 003652-0247-1993
[41] 003644-0147-1997
[42] 000512-0125-1993
[43] 000517-0201-1997
[44] 000517-0218-1993

sublicense.

The two-and-a-half to three-year time frame required for the preparation and submission of TDT proposals, the award of the grant, the performance of the research and the development of these projects is a long time in many industry sectors. Two agricultural technologies showed great promise but changes in world markets dampened interest in licensing. PIs expressed regret that industrial sponsors either lost interest in or simply came to neglect the research projects. Problems associated with the non-synchronous phases of research and market cycles may be unavoidable. For example, two leading industrial R&D companies sponsored a project that successfully developed a technology that performed precisely as hoped for at the project's inception. But, by the time the project had concluded, both sponsors had divested the divisions that originally championed the research. A multitude of unforeseen circumstances can arise that could never have been anticipated when the TDT proposal would have been submitted.

Many projects succeeded scientifically but failed commercially because the PIs who wrote the project proposals poorly planned the steps toward commercialization or had little or no training in the technique of getting an idea to market. PIs in some instances were incapable of researching the market or failed to diagnose market conditions properly. In some cases PIs believed that the industrial sponsorship agreement from the outset had turned the IP over to the research partner, both exclusively and non-exclusively, in two cases for a nominal consideration of $1 for license fees. In another set of cases, a few PIs thought the tech transfer was to have occurred naturally when the university and industrial researchers worked jointly on the projects.

Particular institutional technology transfer offices were cited several times as being barriers to commercialization. Stumbling blocks mentioned were: patent application delays; lack of understanding of the technology; and no interest and lack of aggressiveness in discussions with licensing or potential licensing partners. In a few situations, frustration was expressed with failed licensing negotiations after projects were completed. In one case, a company in Oklahoma was spun out of a TDT project , and the PI said that he did not believe anything would have come of the technology if it had stayed at the university in Texas.

TECHNOLOGY TRANSFER

Irrespective of any directly traceable economic benefits, the successful transfer of technology as a result of the research agendas of many PIs in a few cases was found to contribute to the amelioration of societal problems. One team's research was a technical success and was promoted, first in mammography, and later, in other applications in bone assays for the early onset diagnosis of periodontal gum disease before symptoms occur.[45] A PFC technology tied to the fate of the Kyoto Agreement (if implemented) offered

[45] 010366-0230-1993

substantial promise. Another PI intends to take on the challenge of drug-resistant bacteria to cure disease.[46]

Matching TDT funding has been instrumental in reducing financial risk to a level that encouraged a for-profit partner to co-invest. As one example, the commercialization of a technology whose purpose is to eradicate blindness is moving forward with human trials and with public funds leveraged through private sources by a factor of ten.[47]

ONGOING RESEARCH

Some project results may have been less than ideal but a continuing path in an ongoing research program had been opened up. Although sensors that detected agents in blood were not stable, one project led to other TDT projects that were very successful.[48] Although during the course of a project the entire field lost its market potential for product development, the TDT grant led to major NIH funding that played a crucial role in further development.[49] Although the outlook for the targeted industry was negative, substantial research contracts arose from bio-tech companies as a result of a transgenic crop technology.[50] In a case where research was not sufficiently mature to warrant moving toward commercialization, a subsequent project built upon prior results that ultimately led to a commercialized patent.[51] A failed spin-off company without a good customer base led to an improved class of sensors and a new sensor technology resulted.[52] The massive depression in the telecom industry was the major cause for failure to commercialize another project.[53] Another TDT project led to NIH Phase I and II grants for a software program functional in the early detection of the progression of blindness.[54]

ADDITIONAL FUNDING

In many projects, a significant amount of additional funding raised by a PI could be attributed to the credibility earned as a result of TDT awards. The MD Anderson Cancer Center received a $25M gift from a patient to continue work begun with assistance from a TDT award. Most large grants ($750,000 or more) were awarded by federal government agencies including the National Institute of Health, the Air Force Office of Research, Defense Advanced Research Projects Agency, and the National Science Foundation. Follow-on grants from industry sponsors typically were found to total less than $100,000 each. Although it is not always possible to determine a cause-and-effect

[46] 010674-0065-1995
[47] 003652-0339-2001
[48] 010019-0141-1993
[49] 004952-0061-1993
[50] 003644-0050-1993; 003644 0046 2001
[51] 000512-0082-1995
[52] 000512-0172-1995
[53] 000512-0436-1999
[54] 003644-0217-2001

relationship between follow-on grants and TDT awards, there is no question that frequent and substantial external follow-on funding of research occurs as a consequence of TDT proposal selection.

PERSONAL AND CAREER REWARDS

Due to affiliation with the TDT, several PIs show personal and professional transformations in the laboratory and in their involvement in the for-profit sector. One PI states that his relationship with the TDT program has been rewarding in terms of ongoing research and industry interest in that the program changed how the PI operated. Prior to his first TDT award, he concentrated on pure science and basic research, but after his involvement with the TDT program he concentrated on research targeting commercial goals, eventually producing 45 patents generating royalty income.[55] One particularly tenacious PI repeatedly altered his research stream in his search for an industrial partner with distribution channels for his invention of compatible facilitating agents.[56]

Many of the PIs interviewed cited the benefits their students had received. Interaction between the students and industrial sponsors was particularly highly praised. Students involved in TDT projects were exposed to “the real world” in the field they were studying, and they were allowed to establish relationships with industrial sponsor researchers and, in some cases, to be recruited after graduation. One PI, currently a department chair, stated that a TDT project allowed his institution to build a reputation that attracts top students who may have otherwise attended Stanford or MIT. A PI reported that numerous students who worked on his project went on to complete their advanced degrees and are now employed in related industries at major technology corporations. TDT projects also produced positive changes in the curriculum of courses taught by PIs, including strong integration of the research into existing courses and the development of new courses based on the research.

CONCLUSION

The TDT plays a dominant role in shaping the research programs of members of the academic scientific community in Texas. Many PIs awarded TDT grants report that their research results have been beneficial to their scholarship. For many entrepreneurial researchers, TDT grants are critical to technology commercialization. TDT funding often plays a pivotal role in reducing the risk associated with venture capital investment in high-tech commercialization in Texas. National and international benefits accrue from TDT-funded research, and in many instances rich financial and scientific rewards have been returned to the State of Texas as a consequence of the TDT Program.

[55] 003652-0260-1993
[56] 010366-0152-1999; 010366-0113-2001

3.2 ATP Findings

HIGHLIGHTS

- 128 PIs responded to five questions regarding 143 ATP-funded projects.
- About 21% of ATP projects were commercialized.
- About 36% of ATP projects either were found to have no immediate commercialization potential or were awarded to a PI who had no commercialization interest.
- More than 90% of the PIs received follow-on funding as a direct result of the ATP award.
- NIH and NSF accounted for slightly less than 20% of follow-on funding awards.
- Federal awards and private companies/foundations each accounted for 3 in 10 follow-on funding awards.
- The Welch Foundation was the single most generous foundation in terms of follow-on funding.
- One in three ATP projects produced a measurable economic impact within Texas.
- More than one-fourth of ATP projects that are not yet commercialized continued to hold promise of commercialization.
- A majority of PIs considered the human capital represented by newly trained students the most overlooked positive economic impact of ATP projects.

We conducted a telephone survey of 160 principal investigators (PIs) to further clarify their views about the impact of their ATP projects. The survey centered primarily on questions of commercialization, economic impacts, and additional funding. We completed a total of 128 interviews between June and August 2004; 32 PIs did not respond. A template prompted the interviewers to pose five predetermined questions during each interview. The responses were aggregated into a database.

<u>Question 1.</u>

Is there commercialization activity as a result of this project? If no, what prevented/hindered commercialization? Are there ongoing efforts to commercialize? What are they?

Without question, a substantial number of ATP projects have been a catalyst for some form of technology commercialization. Of the 128 completed interviews, 21.7% of the PIs indicated that an ATP project directly resulted in some appreciable level of commercialization activity. For projects that did not result in any commercial activity, PIs offered detailed descriptions of the factors that had hindered commercialization. We also documented any pending realistic plans to commercialize technology.[57] We divided the 143 responses into the following categories:

- Commercialization activity resulted (21.7%)
- PI was able to collaborate with industry (17.5%)
- PI received additional funding (7.0%)
- Further research generated by the project (15.4%)
- Projects have potential (8.4%)
- PI made no attempt to commercialize (10.5%)
- Project had no material impact (10.5%)
- No comment or no relevant comment was made (9.1%)

Commercialization activity resulted. In the case of 31 projects, PIs reportedly engaged in commercialization activity that resulted in licensing revenue and/or the formation of a company and/or the realization of process savings. Many of the grants that funded projects were awarded to PIs whose relationship with industrial partners was well established and whose background included prior successful commercialization experience. In some instances, the movement of technology toward commercialization was initiated by a company that identified the PI through patent application records. Other comments were similar to that of one PI who said his ATP grant was "instrumental in speeding up the process of commercialization."

PI was able to collaborate with industry. In the case of 25 projects, PIs reported that their attempts to collaborate with industry were successful. PIs developed initial contacts with industrial partners as a direct result of the research conducted during the ATP project. Often PIs collaborated with companies to obtain follow-on funding, making joint applications for SBIR grants and funding from other sources.

PI received additional funding. In the case of 10 projects, PIs attributed any additional funding received as a significant commercial activity in itself, implying that, to date, the most significant step toward commercialization was limited to the goal of acquiring additional funding (for research, patent expenses, etc.).[58] Any additional funding received often affected not only a current ATP project, but also other research activities. One PI stated, "The ATP grant was critical in receiving the additional funds. Some of the money received was funding several projects simultaneously." Another PI commented that "the ATP grant leveraged itself at least 10 times."

Further research was generated by the project. In the case of 22 projects, PIs commented that the primary impact of a project was the generation of further research. In many instances, this result was achieved by PIs who were able to obtain additional

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[57] Where a PI's response was relevant to more than one category, the comment was included in all applicable categories. If a PI with multiple awards made the same comment for each, the comment was recorded only once.

[58] It is important to note that due to multiple categorizations, projects recorded in this category also may have been involved in other forms of commercial activity, such as "Collaboration with Industry."

funding for research originally undertaken in the ATP project. Additional funding also made possible the refinement of scientific findings and opportunities to conduct research in related areas. A few projects were directed at what PIs unequivocally considered "basic science." Projects included in this category did not generally lead to tangible monetary benefits for the PI or the institution, whereas projects in the additional funding category oftentimes did.

Projects have potential. In the case of 12 projects, PIs thought that technologies would have potential. In some projects, although the research was believed to be patentable and/or commercializable, the PIs expected that additional time would be required before either result could be achieved. Many PIs were confident that the approval of a major federal grant was pending, and when finally approved, commercial benefits from the project would be realized. One PI commented that if the technology was commercialized, "they would reopen a large factory in Texas that has been closed down for close to 20 years and could employ at least 30 people." The estimated cost of the factory's renovation was $2.5 million.

PI made no attempt to commercialize. In the case of 15 projects, PIs did not attempt to commercialize their products. Interestingly, one in ten PIs felt that the researcher's role was to conduct research and leave commercialization to others. In some instances, research results were placed, either by default or deliberately, in the public domain with the goal of benefiting society as a whole. Several PIs believed that neither their basic research nor process patents were fit for commercialization (for example, a process to manufacture silicone wafers), and therefore any commercial activity was effectively preempted. One PI commented that most universities do not attempt to commercialize a process patent because of the difficulty with enforcement.

Project had no material impact. In the case of 15 projects, PIs commented that projects had no material impact. One in ten projects had not made significant economic impact to date and did not manifest the potential for any future economic benefits. One PI entered the initial stage of collaboration with industry, but following a market study conducted by the company, it was concluded that the technology's potential was limited. Other PIs reported the need for more time, funding, and other resources before the prospect of commercialization could be promising. PIs in some instances concluded that projects would never yield anything economically worthwhile and had moved on to other research.

No comment or no relevant comment was made. In the case of 13 projects, PIs either did not respond to the question or the response did not contain information from which any relevant data could be derived.

<u>Question 2.</u>

Did this project result in additional funding for your institute or for your industrial sponsor(s)?

A high percentage of ATP awards have led to additional research funding. Of the sample set, more than 90% of the PIs indicated the award of follow-on funding. Frequently, PIs received funding from multiple sources.[59] We divided the 255 responses into the following 15 categories:

- NIH and NSF (11%) and (7.8%)
- Various defense agencies (15.3%)
- Various federal sources (4.7%)
- DOE (3.9%)
- Private companies/foundations (26.3%)
- Welch Foundation (3.1%)
- Texas State sources (5.1%)
- ATP, TDT, and/or ARP (3.5%)
- Equipment and/or in-kind donations (3.9%)
- Agricultural research (4.3%)
- Royalty income (0.8%)
- Additional business (1.6%)
- Not-for-profit entities (1.2%)
- Miscellaneous (1.2%)
- No response (6.3%)

NIH and NSF. In the case of 28 projects, the National Institutes of Health (NIH) awarded additional funding; the National Science Foundation (NSF) awarded additional funding for 20 projects. Most PIs reported that the additional funding was a direct consequence of the ATP award. The most common belief held by PIs was that the ATP project established or enhanced the PI's credibility in the eyes of the succeeding sponsor. According to many PIs, subsequent to a successful ATP project, NIH and NSF were more inclined to provide follow-on research funding for the same or an entirely new research project. In some instances, a single PI received several successive follow-on grants. Frequently, PIs reported multiple NIH and/or NSF grants over the course of their career as a direct result of successfully obtaining an ATP grant.

Various defense agencies. In the case of 39 projects, PIs received additional funding from various defense agencies including the Department of Defense, the Office of Naval Research, various administrative units within the Army, and other agencies, offices, and departments. PIs also frequently reported receipt of SBIR grants in collaboration with an

[59] Projects leading to awards from multiple funding sources were recorded in multiple funding categories as appropriate. When a PI received multiple awards from the same source, the projects were included only once in that particular funding category. Where a PI was interviewed about more than one ATP project, the projects were treated independently, and the responses were recorded with multiple entries. An administrative unit of an agency was recorded in a single category separate from the agency if the unit had funded multiple projects. For example, although the National Institute of Health (NIH) is a federal agency, it was recorded in a stand-alone category, whereas smaller federal funding sources were grouped into a "Miscellaneous Federal Funding" category.

industrial partner.

Various federal sources. PIs were awarded additional funding by various federal sources for 12 projects. Included were any federal administrative units not accounted for in other categories, or federal funding without indication of the specific source.

DOE. The Department of Energy (DOE) awarded additional funding to 10 projects. In some cases, the DOE also provided PIs with resources necessary for research. For example, one PI received $400,000 from the DOE, and the DOE also provided two hydrogen tanks valued at $100,000 each.

Private companies/foundations. Sixty-seven project PIs received additional funding from a variety of private companies/foundations. A group of diverse companies, including Texas Instruments and SEMATECH, funded multiple PIs. A single industrial sponsor awarded $1.2 million in sponsored research funds to a PI who reported that the size of the award was directly attributable to the credibility gained from the prestige of the ATP award. Of the private foundations, the Welch Foundation, which specializes in funding basic research in chemistry, funded 8 awards.

Texas state sources. A variety of Texas State sources other than the ATP, TDT, or ARP awarded PIs of 13 projects additional funding, including city governments and other unnamed state sources. The most notable project in this category received more than $3.8 million from the City of Houston for "applied research and testing." The PI reported that receipt of the ATP grant had given him the confidence to seek this funding.

Texas ATP, TDT, and/or ARP. In the case of 9 projects, PIs were awarded additional funding from the ATP, TDT, or ARP. PIs commented that because subsequent Texas awards were directly attributable to earlier ATP projects, it seemed appropriate to report ATP, TDT, and ARP funding.

Equipment and/or in-kind donations. Ten PIs received equipment and/or in-kind donations from funding sources in addition to monetary funding. Texas Instruments donated equipment on numerous occasions.

Agricultural research. Sponsors with interest in agricultural research awarded additional funding to PIs in 11 projects. The United States Department of Agriculture (USDA) was found to be the most frequently cited source and demonstrated a pattern of consecutive awards to support the research of a number of different PIs.

Royalty income. Two PIs earned royalty income from licensing activity that arose from the ATP project. We recorded royalty income as additional funding in the cases where the monies funded follow-on research.

Additional business. Four ATP PIs benefited from additional business and viewed the financial benefits as attributable to the ATP project. For example, one PI received contract work for specific research projects totaling $150,000.

Not-for-profit entities. In the case of 3 projects, PIs received additional funding from not-for-profit entities such as the American Association of Medical Colleges (AAMC).

Miscellaneous. Three PIs received additional funding from miscellaneous entities that could not be included in any other category.

No response. Sixteen project PIs either did not respond to the question or the response contained no information that clarified the additional funding received.

Question 3.

Note: This section concerns student and educational impacts and is addressed separately elsewhere in this report. See Chapter 6, *Effects on Students and Educational Processes*.

Question 4.

What other factors, if any, related to the project have caused/provided an economic impact?

Principal investigators repeatedly asserted that ATP projects had brought about a variety of economic impacts, not only in Texas, but also nationally. PIs were asked to list factors that played a role in statewide economic impacts.[60] The following categories were developed from the 138 projects:

- Collaboration with outsiders – academia and industry (14.5%)
- Research-related economic impacts (21.0%)
- Educational economic impacts (13.8%)
- Economic impact via pending commercialization (28.3%)
- Economic impact not material (5.1%)
- Economic impact occurred outside Texas (2.2%)
- No comment or no relevant comment was made (15.2%)

Collaboration with outsiders – academia and industry. The primary economic impact for 20 ATP projects was the opportunity for collaboration with outsiders. PIs frequently reported that they made important industry contacts through their work, leading not only to additional funding but to collaboration on commercialization goals as well as consulting contracts. PIs also indicated that ATP projects led to further collaboration with colleagues, citing many instances of further research in related areas and establishment of

[60] Projects that produced multiple economic impacts were included in more than one category where appropriate. Where questions were put to a PI with more than one ATP project, the projects were treated independently and responses for each of the projects were recorded in the appropriate categories.

longer-term working relationships.

Research-related economic impacts. In the case of 29 projects, the primary economic impacts were broadly considered research related. PIs mentioned citations of ATP projects in numerous articles and publications, which in turn led to more research being undertaken in Texas. PIs commented that the follow-on research resulting from ATP projects was often commercializable, and ultimately led to process savings, creation of jobs, or royalty income. (Note that projects that directly resulted in commercialization are categorized below.) One PI lamented that "although the project was scientifically rich (and interesting), it did not have much of an economic impact because it did not have any commercial applications." In contrast, one PI noted, "The ATP project has spawned many other research programs, which have led to the formation of many new companies."

Educational economic impacts. For 19 projects, the primary economic impact was categorized as educational. Students benefited from valuable education and training they received through work on the projects. Upon graduation, some students remained in research while others entered various positions in industry. PIs also commented that their ATP project(s) contributed to their own scholarship and substantive knowledge. A widely cited educational impact was the integration of research findings into course curricula. One PI said the software developed in his ATP-funded research received favorable student reviews and was rated as the best learning tool in class, over and above conventional learning methods.

Economic impact via pending commercialization. In the case of 39 projects, the primary economic impact of the ATP project is expected to occur via pending commercialization. Though these PIs indicated that the projects have not realized economic benefits to date, in the future, benefits from commercialization were certain. Anticipated benefits were job creation, licensing revenues, and industrial collaborations. The technology developed by one PI reportedly will be adopted by an industrial partner to provide a service "that will examine the air quality in houses and detect any anomalies." For projects that showed substantial commercial potential, although actual commercialization had yet to occur, some PIs were awaiting governmental approval or final negotiations with an industrial partner were required before commercialization could move forward.

Economic impact was not material. The primary economic impact of 7 projects was deemed "not material." Several PIs had no intention of becoming involved in the commercialization process, believing that commercialization should not be a preoccupation of university-based researchers. In other cases, PIs and/or the university's Office of Technology Licensing suspected the project would not result in commercialization for a variety of reasons, i.e., the research findings were preliminary or the intellectual property was not patentable.

Economic impact occurred outside Texas. The primary economic impact of three projects occurred outside Texas. One PI commented that although the "Texas-specific economic impacts have been minimal, the ATP-funded work allowed the work to be visible to those who needed the technology." Another PI collaborated with the international division of a multinational corporation, and although Texas may not see economic benefits from the project, it would impact workers overseas.

No comment or no relevant comment was made. No comments about economic impact were made about 21 projects. PIs stated it would be hard for them to qualitatively or quantitatively evaluate the economic benefits. In a number of cases, the PIs replied that information was proprietary and could not be divulged.

Question 5.

Anything at all related to the project that has not been covered in the survey or this interview?

The 132 responses to this catch-all for diverse responses[61] were divided into the following categories:

- Comment alluded to an aspect of the ATP program (23.5%)
- Comment related to commercialization (15.2%)
- Comment regarded the educational impact of their project (26.5%)
- Comment contained no pertinent information (15.9%)
- No comment or no relevant comment was made (18.9%)

Comment alluded to an aspect of the ATP program. PIs for 31 projects commented negatively or positively about a particular aspect of the ATP program. Of this number, 17 PIs commented on the ATP review process whereas 14 PIs commented about the ATP funding process. The opinions of the PIs varied significantly. For example, several expressed gratitude to the ATP application review committee for awarding funding even though the PIs had not yet established a record of funded research at the time of application. Other PIs stated that current research projects would not have been possible without the ATP. However, some PIs considered the current application review process inadequate. These PIs thought that reviewers lacked a thorough understanding of the research areas, and meritorious projects were often denied funding. One PI felt that the review process had been too short sighted. PIs opined that in order to evaluate the benefits of a particular project, reviewers should be willing to look beyond the current 2-3 year horizon and should "get accustomed to looking 8-10 years down the road." Other PIs who had received ATP funding many years before but had not been approved for any subsequent grants were often unhappy with the current ATP program. They stated that

[61] Where a PI's response was relevant to more than one category, it was recorded in each appropriate category. Where the PI was interviewed for two ATP projects and made the same comment for both projects, response was included in only one category.

the ATP funding process had evolved (for the worse) over the years. Finally, a number of PIs felt that ATP had narrowed the funding to specific research areas. [62]

Comment related to commercialization. PIs for 20 projects commented about matters related to commercialization. Thirteen PIs commented on matters specifically related to commercialization at their university, whereas 7 PIs commented on the need for outside help for commercialization. Comments ranged from PIs who were satisfied with the Office of Technology Commercialization (OTC) at their specific universities to those who felt that their OTC was grossly understaffed and, as a result, could not do much to help. PIs also voiced dissatisfaction with the lack of support from a local technology incubator during the commercialization process. Many PIs saw a need for an independent entity whose sole purpose would be to review the findings of ATP projects so that those with substantial potential for commercialization could be aided further.

Comment regarded the educational impact of their project. The PIs for 35 projects commented about the educational impact of their project. These comments tended to emphasize that their projects had enhanced “human capital” through the invaluable training students had received. Although the majority of PIs noted their projects had inculcated advanced research skills, others mentioned that the projects had provided an opportunity for students to learn about entrepreneurship.

Comment contained no pertinent information. PIs for 46 projects did not provide additional information.

[62] Additional comments along these lines are described in further detail in sections 9.3 and 9.4 of this report.

Chapter 4: Case Studies

In order to provide in-depth and qualitative information regarding ATP/TDT project outcomes, thirty-one case studies of individual projects were developed. The original intent was to select projects in three general categories or subsets:

(1) projects whose outcomes have been sub-par, with a bias toward legal issues, as legal disputes arising from technology commercialization are neither rare nor trivial;
(2) projects with outstanding commercialization experiences;
(3) projects with promising opportunities for future success at this time.

Based on the large number of possibilities identified in the in-depth, non-attributable interviews conducted with PIs (presented in Chapter 3), more emphasis was placed on the latter two categories.

Project staff selected the cases in a non-random manner, however, a deliberate attempt was made to develop cases across many different research areas and universities. The list of projects, the PI, and university affiliation are displayed at the end of this chapter.

Each case study was prepared from a combination of different information sources, including material submitted by the PIs to the Coordinating Board, phone interviews, and in some instances, interviews were performed with co-PIs, industrial partners, individuals at start-up companies, and public information sources. Each PI was requested to review case study drafts on their projects for accuracy and interpretation, and all case materials included in this assessment report received approval from the respective PIs.

The case studies presented below represent economic achievements, entrepreneurial successes, and technical and scientific innovations. Each case contains an overview of the project, some background on the research question, a description of the research process, a summary of the technology transfer/commercialization results, and a "Lessons Learned" section summarizing the key impacts of each project. All of the cases represent some form of significant impact on the state's economy, and many contain more than one example of economic benefit to the state. Some cases offer suggestions for improving the ATP/TDT program.

At the risk of oversimplifying the contributions of these projects to the state's economy, the case studies have been grouped by type of impact. In many instances, the groupings were somewhat arbitrary, because numerous case studies have multiple areas of impact. Each group is described at the outset and then individual cases are presented.

GROUP 1: MAJOR FOLLOW-ON FUNDING

Group 1 consists of projects whose PIs all successfully parlayed ATP/TDT awards to subsequently attract large amounts of follow-on funding for their projects, their research, or their labs. ATP/TDT awards were effectively leveraged to bring additional research funds to the state from private foundations and companies, governmental agencies, and other sources, which in turn fostered opportunities for further technology commercialization. Research funding is the life-blood that sustains both basic research and innovation; without it, even the most brilliant researcher will have a much more difficult time finding a commercial market. In every Group I case, the PI reported that ATP/TDT award funding was the key factor in winning subsequent follow-on funding.

Case Study Profile: Tumor Susceptible Mouse Development

OVERVIEW

As a result of his 1989 Advanced Technology Program (ATP) project titled, "Tumor Susceptible Mouse Development: Tumor Suppressor Allele Inactivation," **Dr. Lawrence A. Donehower** of the Baylor College of Medicine received over $1,500,000 in follow-on research funding. Dr. Donehower used genetic engineering methods to develop a mouse that is missing a key tumor suppressor gene called p53. These p53-deficient mice (or "knockout mice") are susceptible to early tumors of various types, have proven very useful for understanding the role of p53 in cancer suppression and have also been found useful by pharmaceutical companies for testing candidate drugs for carcinogenicity.

PROJECT BACKGROUND AND RESEARCH PROCESS

In early 1989, Dr. Donehower conceived of the development of a p53 knockout mouse. In collaboration with Dr. Allan Bradley, one of the world pioneers in the knockout technologies, he embarked on his goal. Dr. Donehower knew the project would be expensive, laborious and time-consuming, and he felt that the Texas ATP would be the ideal mechanism to fund it. In his opinion, the ATP was willing to fund mere ideas if they were good ones and had commercial potential, whereas most funding agencies, particularly the NIH, wanted to review supporting preliminary data before approving funding. Once he and Dr. Bradley received the ATP funding approval, they were able to move forward with research very rapidly. Dr. Donehower is grateful for the support from the ATP, and he appreciates them putting their faith in him and funding this project.

Dr. Donehower generated the p-53-deficient knockout mice by using the (then) newly developed targeting methods in mouse embryonic stem cells. Below is an outline of the procedures used:

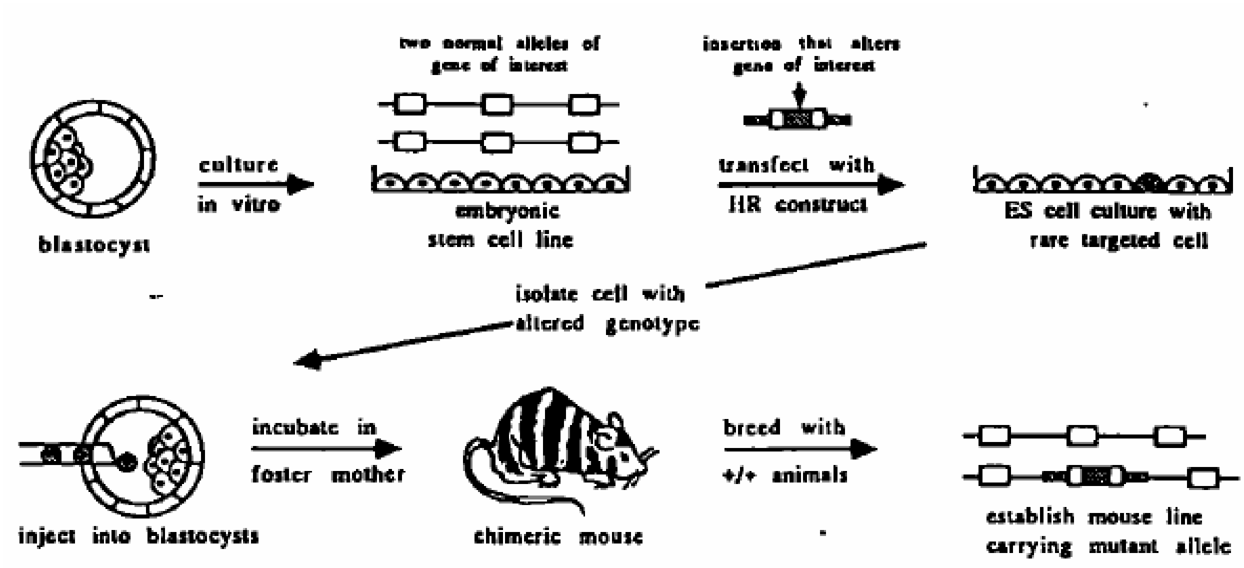


Image courtesy Dr. Larry Donehower

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Subsequent to this project, Dr. Donehower has received millions of dollars in additional funding from a variety of sources. He received several National Institute of Health (NIH) grants, various other governmental grants, including grants from the Department of Defense (DoD) and a Tobacco Research Grant. Dr. Donehower said that he could confidently attribute $1.5 million of his subsequent funding directly to this project. He also received millions in additional funding as an indirect result of the project.

The p53-deficient mice developed by this ATP project have now been approved by the U.S. Food and Drug Administration as one of the acceptable rodent models for testing potential carcinogenicity in candidate pharmaceuticals. Before the introduction of these mice as a test model, the rodent carcinogenicity bioassays then available required a two-year testing period before the FDA cleared new products for release into the market. However, the p53-deficient mice are more sensitive to carcinogen-induced cancers, and their use allows a pharmaceutical company to reduce its testing time to only six months. Thus, the FDA can gather the necessary information with a 75% reduction in testing time. The drug company requires less time to determine the safety of new products, allowing the introduction of new products (assuming FDA approval) into the market more quickly. Other benefits include the availability of new products (especially medicines, drugs, etc.) to consumers and the possibility of profits earned much sooner than previously.

Dr. Donehower also felt that the people at Taconic (his industry partner), particularly Donna Gulezian, were wonderful in consulting with him and his co-PI, which helped make the mice more accessible to interested academic and company-associated scientists. Taconic has an exclusive license (which expires in 2013) to the technology that was developed under this project. Taconic been able to successfully commercialize this technology, and currently has annual revenues of $59 million. The project allowed Baylor and Taconic to develop a working relationship with significant mutual benefit.

LESSONS LEARNED

During the initial phases of this project, the key accomplishment was the publication of an article describing the mice in *Nature* in March 1992, recognized as a highly cited landmark paper. Since then, Dr. Donehower and Dr. Bradley have published over 30 papers characterizing the p53 knockout mice, and hundreds of papers by other investigators have utilized p53 knockout mice and derived cells. He also commented that this project contributed in a small way to the general strengthening of Baylor's scientific reputation, its research funding levels, and perhaps its ability to recruit students and researchers. He confirmed that this project certainly had a major positive effect on his own scientific program and made it easier to recruit talented students and postdoctoral applicants.

Since the generation of the p53 knockout mice, Dr. Donehower and Dr. Bradley have had an outstanding collaborative relationship and have coauthored more than twenty scientific papers. Once they had generated the p53 knockout mice, the PIs received significant help from Baylor's Office of Technology Assessment (OTA). Dr. Donehower commented that he had a rewarding experience with Baylor's OTA, which was particularly efficient and helpful in arranging the patent process and commercialization of the mice.

Case Study Profile: Low Emission Catalytic Converters

OVERVIEW

Ongoing industrial collaborations and state technology grants have resulted in new designs for catalytic converters in both diesel and gasoline engines, through independent and collaborative efforts of **Drs. Balakotaiah and Harold** of the University of Houston. These ATP projects are simultaneously strengthening ties between a Texas University and local industry, supporting expansion of a Texas company, addressing Houston’s current pollution issues, and drawing millions of dollars in economic benefits to the State of Texas through the Center for Diesel Emission and Clean Engine Technology in Houston.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Vermuri Balakotaiah, Professor of Chemical Engineering at the University of Houston, began his research in 1998, as a result of the increasing vehicle emissions restrictions throughout the country. In 1999, he was awarded an ATP grant to explore how catalytic monoliths can be redesigned to reduce cold-start emissions in gasoline combustion engines as low to zero emission vehicles were becoming more important to the economy. In 2000, Dr. Michael Harold joined the University of Houston and Dr. Balakotaiah in addressing these pollution concerns. Both professors were awarded 2001 ATP grants to expand their research and Dr. Harold, Dow Chair Professor and Department Chair at the University of Houston, was subsequently awarded a TDT grant in 2003 in collaboration with Engelhard Corporation of New Jersey, to explore designs that would significantly reduce nitrogen oxide (NOx) emissions from diesel engines.

Dr. Balakotaiah discovered that most pollution from gasoline engines is produced within the first three minutes of turning the key and research has resulted in new catalytic converter designs that can reduce pollution of cold start emissions up to 90% based on computer models. Similarly, Dr. Harold has produced diesel converter designs that reduce NOx emissions by at least 90% in bench-scale testing, a great leap forward in the fight against smog. Outside support for continuing research has been awarded through the Gulf Coast Hazardous Substance Research Center ($50,000 per year) and industrial collaborations with Engelhard Corporation ($150,000) and Dow Chemical ($275,000) of Freeport, Texas. Additional support is pending from Ford Motor Company of Michigan, Cummins Diesel of Indiana, the Texas Commission on Environmental Quality (TCEQ), and the National Science Foundation.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

As a result of the industrial collaboration between Dr. Balakotaiah and Dow Chemicals of Freeport, Texas, $65,000 in unrestricted support was given during the term of the 1999 ATP grant and renewed to a current total of $275,000, exemplifying industrial commitment to reducing pollution. Dow Chemicals employed Dr. Balakotaiah as a consultant, which has led to several new catalytic converter designs and patents that are currently being tested. If the tests are successful, it could have an impact on air pollution and bolster sales for the Texas-based chemical company.

Occurring in parallel with his 2001 ATP grant, Dr. Harold approached the City of Houston and was ultimately awarded $3.8 million to conduct applied research and testing. The City award resulted in the establishment of the Diesel Emission Research and Testing Facility to help Houston address the State of Texas plan to reduce emissions by 2007. Besides fundamental research, the facility will be used to test third party products on City of Houston vehicles in hopes of speeding commercialization. Similarly, it is anticipated that the Center will attract state funding to help implement the Texas Emission Reduction Plan (TERP). The facility could accelerate the

"Command Center" of the UH Diesel Vehicle Research and Testing Facility
Source: http://www.egr.uh.edu/news/0604/?e=dieselfacility

qualification process of the TERP program, which involves providing incentives to local governments and industries to reduce pollution. Up to $2.5 million in construction and facility costs have already been invested through funds from the University of Houston and City of Houston. It is anticipated that an additional $5 million will be invested in an expansion of the facility. The project currently provides four jobs and construction contracts to the local economy, and employment is expected to increase in the future.

Dr. Harold and Dr. Balakotaiah formed an additional industrial collaboration through a 2003 TD&T grant with Engelhard Corporation of New Jersey, bringing an additional $150,000 to Texas-based research. Directly linked to the Diesel Emission Center, the team has been working to make these new designs more practical and commercially attractive to industry.

LESSONS LEARNED

An initial $110,000 ATP grant has led to an additional $445,000 in state technology grants and indirectly resulted in $4,375,000 in economic activity to reduce emissions pollution in Texas. The Diesel Emissions Center, through collaborations with government agencies and industrial sponsors, will assist in pollution reduction through applied research and testing and lead to new business growth in Houston.

All of the industrial connections have been established independent of the University of Houston Technology Transfer Office through efforts of Drs. Balakotaiah and Harold. According to the PIs, the Office has made it difficult to work with industry collaborators, as disputes over patent ownership and royalties have decelerated the research process. If negotiations fail, private industry can freely continue the research and patent their discoveries without university affiliation, because Drs. Balakotaiah and Harold have published all of their taxpayer-funded discoveries in the public domain.

Case Study Profile: Transplantation of Bone Marrow Mesenchymal Stem Cells in Dog Hearts with Myocardial Infarction

OVERVIEW

In the initial stages of this project, undifferentiated stem cells were be extracted from a dog's bone marrow and then injected into a purposely-created infarct site on the dog's heart. The goal was to cause normally non-proliferating cardiac myocytes to grow instead of non-functioning scar tissue, which usually forms over the damaged tissue. This procedure was shown to work and received expedited FDA approval to begin Phase 1 studies on humans. The project also was partially responsible for attracting a large donation to the University of Texas Health Science Center at Houston (UTHSCH) Medical School.

PROJECT BACKGROUND

To validate and further the work done in previous studies, researchers performed heart surgery on dogs to create a myocardial infarct site and then injected the infarct site with mesenchymal stem cells (MSC) extracted from the dog's own bone marrow. The research indicated that the cardiac myocytes in an infarcted heart would repopulate, thus improving the region's function. The results of these procedures would provide valuable information for the development of a therapeutic process for treating people who have had heart attacks. The process of using MSC would be licensed to an industrial partner for the purpose of commercialization.

The project lead is **Dr. Yong-Jian Geng,** an Associate Professor at the University of Texas Health Science Center at Houston (UTHSCH) Medical School.

RESEARCH PROCESS

The industrial sponsor, Osiris Therapeutics, Inc., is a development stage company whose focus is on "cellular therapeutic products for the regeneration and functional restoration of damaged and diseased tissue." The company is developing an MSC technology and has previously collaborated on research projects in MSC transplantation with UTHSCH. This project was an extension of those efforts.

To date, improved heart function and morphology has been observed following MSC transplantations. While the implanted cells do generate heart muscle as well as blood vessels, they also increase fibrosis. The implanted cells cannot completely restore contractility and the normal structure of the infracted myocardium.

Several groups, including UTHSCH, in collaboration with Procardiaco Hospital in Rio de Janeiro, Brazil, are actively pursuing clinical studies. The initial results of the UTHSCH human clinical trials were published in the February 25, 2003 American Heart Association's journal *Circulation*. The publication was coauthored by the project PI, Dr. Geng.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

An agreement was reached between UTHSCH and Osiris Therapeutics, stipulating UTHSCH's ownership of all intellectual property derived from the study, and Osiris Therapeutics's exclusive worldwide royalty-bearing licensing rights to the technology.

Two students who are continuing to work on the project are both writing their Ph.D.

dissertations on this research.

In March 2004, UTHSCH received U.S. Food and Drug Administration approval to proceed with clinical trials. The trials will be performed in collaboration with the Texas Heart Institute at St. Luke's Episcopal Hospital in Houston.

Also, an anonymous donor gave $25 million to UTHSCH to further stem cell research. The funds will be used to build a new facility and recruit new faculty. The project has not yet received any support from this donation.

LESSONS LEARNED

While the $25 million donation did not directly result from his TDT project, Dr. Geng believes that his research prior to and during the TDT project provided credibility to the potential viability of stem cell research as a new therapy, and thus was instrumental in leading to the donation.

The researcher's existing relationship with the industrial partner made obtaining matching funds much easier. The sponsor knew the personnel who would be working on the project at the university and that this research team has the prerequisite experience, skill and ability to develop the MSC implantation technology. The relationship engendered a level of trust in sharing intellectual property that was necessary to the full development of the technology.

Case Study Profile: Multi-Tool Integration Kernel for Component-Based Architecture Development

OVERVIEW

The ambitious goal of the project was to refine and commercialize a set of previously developed software systems designed for building complex manufacturing systems. The refined systems would be used in the launch of new commercial products by two new Texas companies (Techsus Medical Systems (TMS) and ScenPro), four established Texas companies (Trilogy, Reveille, Texas Instruments and Intellection), and in the launch of new ventures by manufacturing industries (CTA Incorporated and Factory Controls).

PROJECT BACKGROUND

PI **Dr. Karen Harbison** of UT Arlington (deceased, 1996) and co-principal investigator Dr. Suzanne Barber of UT Austin wanted to address the lack of tools supporting intelligent manufacturing. They had developed the core systems, Scenario-based Engineering Process (SEP), multi-tool kernel (Yellow Rose) and SEPTools with funding from a 1991 ATP grant and a DARPA (Defense Department) grant. The public domain and patent protected technologies were already being used as development tools to support manufacturing processes by companies such as Texas Instruments, Rockwell, Oracle and Digital Equipment Corporation.

The work on the project was done at the Center for Advanced Engineering and Systems Automation Research (CAESAR) at the University of Texas at Arlington (UTA) and at the Laboratory for Intelligent Processes and Systems (LIPS) at the University of Texas at Austin (UT).

RESEARCH PROCESS

Since the core of the technology had already been developed, the focus of this project was the refinement, maturation and commercialization of the existing set of tools. The goal included incorporating sets of requirements from DARPA and ScenPro into the application as well as making it more viable commercially. Researchers worked with CTA, one of the initial industry sponsors, to incorporate the SEP technology into two of their existing tools. Initially industry principals worked with students at the university labs. Subsequently, both the industry participants and the students transitioned back to the company. This process ultimately proved invaluable in both the transfer of the technology and for the students' education and real-world experiences.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Working closely with various industrial sectors was vital to the understanding of what a set of tools would have to provide to be a commercially viable product. The PIs were actively involved with a range of consortia, from trauma care to computer-aided education, with UT-Arlington becoming the lead for two. The involvement and leadership allowed the universities not only to learn the requirements of the industry but also to help define the standards that the industries would use.

As the tools and processes were refined and gained exposure in national and international companies, the need for training in the use and implementation of the process also grew. Two new Texas companies, Automation Through Software and Automation Engineering, collaborated to create instructional material covering "formal life cycle engineering processes" that SEP was designed to address. Courses were also developed and taught in graduate programs at both UT Arlington and UT Austin.

ScenPro was established in 1992 to manage the business generated by the SEP related processes and tools. SEP is a process that uses scenarios as a basis to define and formally document both user and system level requirements. Although ScenPro does not license the process to any other organizations, it does employ the methodology as part of its research and development process. There exists a long list of DoD customers, two private sector companies in the defense industry and two others including Oracle. Only one of the current customers was an industry sponsor of the project—all others are new customers.

SEP was a major factor in UT Arlington's CAESAR group being awarded over $75 million in grants and contracts in 1994 and 1995. The funds supported over 50 faculty members, students and staff in a range of R&D activities. The grants and contracts allowed undergraduate and graduate students to travel throughout the world acquiring knowledge in a range of areas that then was incorporated into the models. As a result, major companies have heavily recruited students associated with CAESAR.

LESSONS LEARNED

Active involvement and leadership in non-academic consortia and workshops created visibility for the project and, more generally, the associated research being done at UT Arlington and UT Austin. The higher visibility led to contributions to the process of setting national and international standards and the development of curriculum, and enhanced prestige for the two universities.

This project to the benefit of the computer sciences departments at UT Austin and UT Arlington allowed the PI and co-PI to raise significant amounts of additional grant money. Dr. Harbison's work at UT Arlington almost single-handedly allowed the university to achieve Carnegie Doctoral Research Executive status. And since the project began, Dr. Barber has raised approximately $12 million to build a world-class computer lab at UT Austin.

According to Dr. Barber, TDT grants have a significant advantage over most other grants in that the funds support students primarily, not faculty and staff. The focus has allowed UT Austin's Computer Science Department to attract some of the best and brightest students from around the country. Dr. Barber said, "It is vital that the money goes directly to labs and student research, not to overhead and fringe benefits."

The relationships that have been established with industrial sponsors provide students with opportunities to work on "real-world" problems in cooperation with personnel in industry. The opportunities for industrial relationships have proven effective in retaining students in Texas once they graduate.

Case Study Profile: Manipulation of Grain Quality Parameters in Rice

OVERVIEW

As a result of his 1993 Texas Technology Development and Transfer Program (TDT) project "Manipulation of Grain Quality Parameters in Rice", **Dr. William Park** from the Texas Agricultural Experiment Station (TAES) was able to develop rice varieties to make a quick cooking rice product with enhanced nutritional value. Dr. Park was also able to place some of the technology for using DNA markers that was developed during this project into the public domain. In addition, an incidental discovery made during the 1993 project allowed Dr. Park to receive a TDT grant in 1995 as well. Although both the 1993 and 1995 projects dealt with proprietary technology used in rice preparation, they are independent in their own right. This case write-up will concentrate on Dr. Park's 1993 project, and is an example of opportunities lost due to the progressiveness of overseas (European) industry versus conservative American industry. Currently, Dr. Park is a Professor in Biochemistry and Biophysics at TAMU/TAES.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Park's intent in pursuing the 1993 TDT grant was to provide Texas rice producers and the Texas rice industry with a competitive advantage in the international rice market. He sought to use the technology developed to produce high yielding rice varieties with novel grain quality parameters which could be used to create new, high value rice products. At the time he applied for this grant, Dr. Park had already formed a relationship with an industrial partner that had developed proprietary technology for rice processing. However, all of the rice varieties which responded to this technology had very poor yield and were subject to an unknown source of variation. The goal of the joint project was to develop high yielding rice varieties that consistently responded favorably to their proprietary processing technology.

The TATP project facilitated Dr. Park's work to identify the specific genes responsible for the process interaction and to develop new varieties, thereby creating the new rice product. It also allowed him to expand the scope of the project and led to the discovery of DNA markers for other types of grain quality – both traditional rice quality and also suitability for a very different type of processing technology. This led to a 1995 TDT grant as well as a subsequent grant from the corporate partner. The 1993 project can also be credited with creating DNA markers for other applications in rice production such as improvements in disease resistance.

TECHNOLOGY TRANSFER/COMMERCIALIATION RESULTS

During this project, Dr. Park was able to interact closely with rice breeders and his industrial partner. Dr. Park commented that such a close cooperation among a biochemist, a corporate partner, and applied breeders is a rare occurrence. This three-way collaboration worked extremely well during the project, and led to development of four rice varieties now widely sold in European grocery stores.

A key result of this project was that Dr. Park was able to place almost all of the DNA markers developed during this project into the public domain. Dr. Park commented that the funding from the TDT program played a key role in this. The TDT funding allowed Dr. Park to investigate questions that involved basic scientific knowledge and other types of grain quality – questions that his industrial partner was not necessarily interested in funding or having answered. Royalty-free access to these markers has allowed them to be widely used in the USDA-ARS/Texas A&M rice breeding program, as well as in other rice breeding programs across the country. These markers have had a dramatic impact on the standard procedure for rice breeding. In addition to four varieties developed for Dr. Park's industrial partner, they have also have played an important role in the development of two public rice varieties with enhanced disease resistance and in the development of a different type of specialty rice targeted for the southern US. In part because of the potential demonstrated by this project, the United States Department of Agriculture (USDA) hired a new category 1 scientist as well as additional technicians to work in the rice breeding program in Beaumont.

Additionally, the TDT funding allowed Dr. Park to employ and train graduate students. One Ph.D. student who was supported by these funds is now a professor of Physical and Life Sciences at Texas A&M at Corpus Christi.

The project's success led Dr. Park's industrial partner to approve additional funding in excess of $1 million. Dr. Park also received smaller amounts of research funding from a variety of other sources.

LESSONS LEARNED

This is an example of a project where TDT support allowed broader objectives to be achieved and helped prevent a potential conflict of interest. Had it not been for the TDT project, Dr. Park may have been unable to research basic questions that led to markers for other types of grain quality and for disease-resistant genes and to release them into the public domain. Considering that much of the follow-up research and technology transfer resulted from the basic scientific questions addressed by this project, having only commercialization as the original objective would have had a less favorable outcome.

Dr. Park's industrial partner was a multinational company with a subsidiary located in Texas. However, the Texas subsidiary of Dr. Park's industrial partner did not support Dr. Park's work. Instead, Dr. Park received support from a European branch of the parent company which was more technically innovative and willing to take risks. As a result, the technology developed by Dr. Park via this project first benefited the European parent company, which launched the new product in Europe. The Texas branch of the parent company that deals with rice processing has since shut down and its manufacturing operation has been consolidated with units in another states.

The primary direct benefit to the Texas economy thus far has come from Dr. Park's DNA markers for grain quality and disease-resistant genes and from the additional scientist positions that were created at the USDA-ARS Research Station at Beaumont. It is hoped that the new rice product will soon be available in the U.S. and that it will be manufactured, at least in part, from Texas rice.

Case Study Profile: Polymeric Carriers for Molecularly Targeted Diagnostic Agents for Near-Infrared Optical Imaging

OVERVIEW

As a result of her 2001 Advanced Technology Program (ATP) project, **Dr. Eva M. Sevick-Muraca** from Texas A&M University (TAMU) has received over $3.7 million in follow-on federal funding. More than a dozen students were trained during the project, and most remained in the pharmaceutical research area. The ATP project also allowed Dr. Sevick to develop a working relationship with MD Anderson Cancer Center (MDACC), other Texas universities, and numerous out-of-state universities. The technology has great potential for small animal clinical studies and the multi-billion dollar medical imaging industry.

PROJECT BACKGROUND

Metastasis, the process of malignant cancer cell spread to normal tissues, limits the success of many cancer therapies and is often the fatal stage for individuals with cancer. If metastatic cells can be found early and destroyed before propagating in other locations within the body, cure rates could be improved significantly. Dr. Sevick's project was designed to improve the identification process by development of medical imaging technology that may be far superior to existing technologies. By using near-infrared, fluorescent dyes to locate the metastatic cells and target therapy with a more sensitive imaging device, a major advance would be achieved over current nuclear imaging technologies.

RESEARCH PROCESS

The project plan was to combine the expertise, resources, and technologies available at MDACC and A&M. Specifically, Dr. Sevick's prior research on 'in vivo' cancer technology and Dr. Chun Li's (MDACC) prior work on polymeric carriers would be combined. In addition, contributions would be made by individuals from other institutions (Baylor College of Medicine, Penn State University, University of Pennsylvania, University of Texas at Austin, University of Vermont, and University of Arizona) in instrumentation, mathematics, and molecular agents. MDACC has served as the site of clinical trials associated with Dr. Sevick's technology, and if the trials are ultimately successful, the State of Texas would be the first site for ultrasensitive diagnostic cancer imaging.

The use of a fluorescent dye offers greater sensitivity than conventional methods using nuclear techniques. As an example, the figure below illustrates the comparatively small animal imaging using optical and nuclear imaging with a molecular agent developed by Dr. Sevick's collaborator, Dr.Chun Li of MDACC. Dr. Li used a molecularly targeting peptide labeled with both a radiotracer and a fluorescent dye. On the right is an image obtained from the fluorescent dye which shows that the labeled protein specifically targets implanted human melanoma (M21) on the right hind limb. On the left hind limb is another human melanoma cancer cell line (M21-) which does not express the cell membrane component that is targeted by the labeled peptide. Notice that there is no molecular uptake of the labeled peptide. The bladder "lights up" since the labeled peptide is cleared through the kidneys. The image took 800 milliseconds to acquire.

In contrast to the optical image, the gamma image of the same animal (in middle) required 15 minutes of imaging time using conventional medical imaging techniques. Here the signal arises from the radiotracer labeled on the same peptide which is also labeled with the fluorescent dye. It is noteworthy that the differences in image quality indicate the enhanced sensitivity of optical imaging over the "gold-standard" nuclear imaging tools currently used in the clinic. Indeed, optical imaging may provide the most sensitive approach for molecular imaging without the use of radioactive tracers.

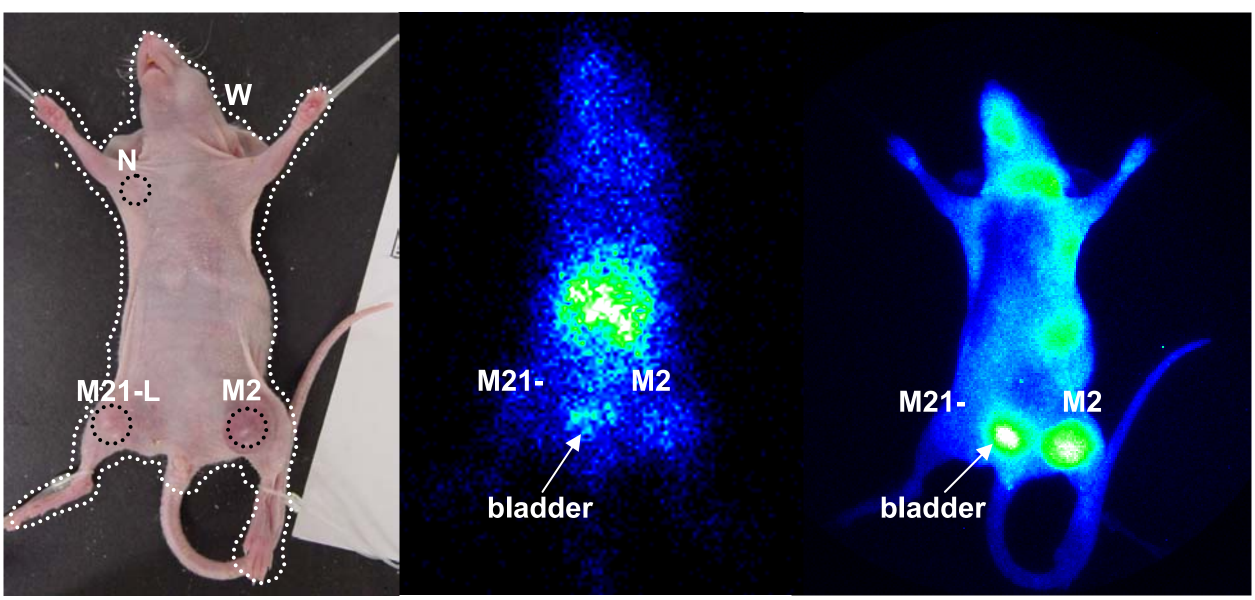


Figure showing white light photograph (left); gamma image (middle), and optical image (right).

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

There are two markets for the technology: (a) small animal imaging for drug discovery in the pharmaceutical industry and (2) diagnostic imaging of disease in humans. General Electric Medical Systems has now licensed the technology for the small animal imaging, and sales are occurring. Pharmaceutical development of therapeutic agents typically requires animal intensive studies in which the distribution and effects of the agent are determined by serial sacrifice of several laboratory animals. By "tagging" the drug with a fluorescent dye, the drug distribution and effect in the animal can be monitored in real time without sacrificing several animals. Tagging could effectively reduce the cost and time associated with animal testing of drug candidates.

In a separately funded project from the National Cancer Institute, Dr. Sevick and her clinical collaborator, Dr. Gary Whitman of MDACC, secured FDA approval for both the medical imaging device and a fluorescent agent for assessing sentinel lymph node status in breast cancer patients within a Phase I clinical trial. Since the lymph nodes are thought to be the first site for cancer metastasis, the project promises to provide a new non-radioactive manner for diagnosis of breast cancer metastasis. In other pending projects, the collaborating teams are seeking to use Dr. Sevick's optical imaging technology to assess molecular action of therapeutic agents in clinical cancer trials. By doing so, it is hoped that the information gained by the sensitive optical imaging technique may provide information that improves the effectiveness of clinical trials, reduces their duration, and thereby lowering the enormous cost of bringing a therapeutic drug to market. Dr. Sevick's imaging technology is understood to be the only one that has approval from the Food and Drug Administration (FDA).

While the small animal testing market is of consequence, it is a small fraction of the entire nuclear imaging market, which now exceeds $7 billion annually in the U.S. Eventually, Dr. Sevick feels that molecular imaging with the optical technology is poised to take over at least fifty percent of the nuclear imaging technology market. If that occurs and Dr. Sevick's technology is found to be satisfactory in human trials, major increases in licensing royalties would follow. More importantly, the diagnostic imaging technology may vastly improve patient therapies and have significant impact on patient survival rates. Even if the technology is superseded by another or does not work as well in human trials, Dr. Sevick's work has brought national recognition to Texas because it represents state-of-the-art molecular imaging technology.

LESSONS LEARNED

From the onset of the project, Dr. Sevick wanted to leverage ATP funding to attract funding from outside the State of Texas. The objective has clearly been fulfilled: (a) in partnership with MDACC, a NIH grant for $1.3 million; (b) in partnership with MDACC, NIH funding and FDA approvals for a Phase I clinical trial; (c) a NIH grant of $1.5 million for Small Animal Imaging Research; and, (d) a National Institute of Diabetes and

Digestive and Kidney Diseases (NIDDK) grant of $900,000 for glucose sensing in diabetes. The ATP project enabled the PI to develop an MDACC relationship, which was crucial to the joint NIH grant applications.

Commercialization of the technology has not been without problems. A difficulty arose early with General Electric regarding possible infringement of intellectual property. After extensive discussions over a period of months, the challenge was resolved with a licensing agreement. A second problem has been the support of her efforts by the technology transfer office staff at her university. She feels the five employees are stretched way too thin, and therefore the office has been unable to provide as much support as Dr. Sevick feels would be beneficial.

Recently, there has been a lingering dispute over Dr. Sevick's collaboration with MD Anderson. Because there has been a complete halt in all research grant proposal submissions regarding clinical translation of the technology, commercialization of this ATP project technology may be impeded.

GROUP 2: NEW COMPANY FORMATION

Group 2 consists of projects that are all notable for the new companies that were spun out of work from ATP/TDT projects. Start-up companies create create jobs, build local tax bases, and generate wealth. The interviewed PI's indicated to our research team that the work funded by their initial awards led directly to the creation of these companies. In most cases, the companies licensed technology created by the PI, hired the PI or graduate students funded by the original award, generated royalty revenue for the PI's university, and brought to market new technologies. Among the principal lessons learned from these cases is that the most successful companies contain both strong scientific expertise and experienced business professionals who understand the markets into which new technologies are brought.

Case Study Profile: Manufacture of Nanotube Reinforced Metals by Containerless Processing

OVERVIEW

Dr. Enrique Barrera's and **Dr. Yildiz Bayazitoglu's** 2001 TDT grant deals with the manufacture of nanotube reinforced metals by containerless processing. NANOTex, Corp. and Stewart Automotive Research (SAR) were the industrial partners for the TDT grant. The cutting-edge nanotechnology in the final preparations for manufacturing and commercial sales can be utilized for a wide range of products. The TDT project has helped the PIs secure a $15 million NASA grant. The project has had a very positive student impact in terms of improved educational experiences for the students involved.

PROJECT BACKGROUND

A demand exists for advanced materials that take incorporate carbon nanotubes offering unique properties of high strength, stiffness, and electrical and thermal conduction. Dr. Enrique Barrera and Dr. Yildiz Bayazitoglu, Rice University Department of Mechanical Engineering and Materials Science, received a 2001 TDT grant titled, "Containerless Processing of Nanotube Reinforced Metal Matrix Nanocomposites." The TDT grant was preceded by two ATP grants in 1993 and 1995 that laid the groundwork for the technology transfer initiative. NANOTex, Corp. and SAR were the industrial partners for the TDT grant. Both companies have their origins at Rice University. The original plan called for the transfer of the technology to NANOTex. NANOTex, with Rice support, that would in turn produce material for SAR. The company's strategy was to accommodate its zone pressure molding (ZPM) process, a method that forms parts by controlled infiltration, to manufacture prototype parts for the automotive industry.

RESEARCH PROCESS

The goal of the TDT grant was to demonstrate the ability to manufacture nanotube reinforced metals by containerless processing. This approach achieves mixing, high dispersion, stability and alignment of nanotubes in metals. Due to the downturn of the technology sector, the objectives of the grant project were modified and the working arrangement with the industrial partners altered. Over the two-year grant period, in addition to the containerless processing method, electro-plating and non-electroplating manufacturing methods were evaluated. The Rice research team took the lead in the revised work program and was supported by NANOTex. Due to economic conditions, SAR was not able to develop the prototype parts for the automotive industry.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

In preparation for the TDT grant research, Rice negotiated a licensing agreement with the two industrial partners covering all aspects of the exchange of the associated intellectual property (IP). The agreement included one Rice patent, two Rice pending patents, and Stewart Automotive Research's zone pressure molding patent. With the agreement all parties secured research-only use rights to the IP during the project period. Ownership of IP that arose during the course of the proposed project would be owned or shared by the inventing party(s). The other parties would be granted rights to use such inventions for research-only purposes. NANOTex and SAR were granted option rights to license such IP from the inventing party(s). The agreement included cooperation in the production of product offerings that may result from the proposed research. NANOTex's primary focus is on the aerospace and oil and gas applications markets. SAR markets to the automotive industry.

A new company, Nanoridge, Inc., has just formed, and has negotiated a master license from Rice for the technology. Rice will be an equity owner in Nanoridge and Dr. Barrera will participate in the new company. Nanoridge is currently finalizing an initial round of funding.

In addition to NANOTex's and SAR's interest in the technology, Rice and Nanoridge are discussing licensing opportunities with two additional companies. The companies are associated with two more fields of use for this technology.

The TDT project has had a significant impact on the PIs' funding support for their research. A $15 million NASA grant was awarded. Discussions are ongoing with the Air Force regarding the technology and Dr. Barrera is putting together a white paper proposal for the Navy.

LESSONS LEARNED

The PIs have found that the ATP and TDT programs are very helpful in developing relationships with industry and accelerating their efforts to get their research out into the marketplace. The grant also helped Dr. Barrera attract a particularly well-qualified Ph.D. student to work on the technology transfer effort.

Dr. Barrera cites three lessons from the efforts to commercialize the technology. First, efforts to secure strong IP protection for a new technology are critical for success in commercialization. Building an IP portfolio is an important and necessary step for a technology startup company. Second, researchers who want to become directly involved in the process of commercializing technology should align themselves with experts that have extensive and successful business experience in a related area of technology. Third, students that participate in ATP and TDT grants earn a chance to gain skills associated with technologies of commercial interest and have the opportunity to work closely with industry. Employment marketability is increased when the students seek jobs after graduation.

Case Study Profile: Thrombin Peptides

OVERVIEW

As a result of a 1989 Texas Advanced Technology Program (ATP) grant for research on "Thrombin Peptides as Enhancers of Tissue and Bone Healing and Inhibitors of

Adhesions and Changes in Vascular Permeability," **Dr. Darrell Carney** of the University of Texas Medical Branch at Galveston (UTMB) started a company called Chrysalis Bio-Technology in 1995. The project also resulted in numerous sponsored research opportunities, totaling in excess of $22 million in follow-on research funding, and led to the human clinical testing of the compounds for multiple therapeutic indications, including diabetes and orthopedic bone fractures. In August 2004, Chrysalis was acquired by OrthLogic of Tempe, Arizona for $34.5 million. UTMB was an equity holder in Chrysalis and thus benefited financially both from the acquisition and the commercialization.

PROJECT BACKGROUND

Dr. Carney's research proposal explored whether TP508, or Chrysalin®, a thrombin mimicking peptide, could accelerate tissue repair in animals with compromised wound healing, i.e. animals with infected wounds, animals that were aged, or animals with induced diabetes. The project also was designed to test if other related peptides could inhibit undesired cellular effects associated with healing and the hemostatic response to injury.

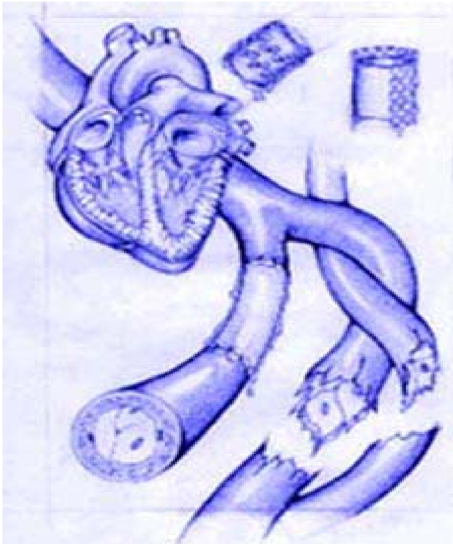
RESULTS OF THE RESEARCH PROCESS

Dr. Carney's research has enhanced the understanding of the role of the enzyme thrombin in tissue repair. Thrombin is a naturally occurring molecule in the body primarily known for managing the blood clotting process, but now known also to play a role in initiating many of the cellular events responsible for tissue repair. (See image.) As a result of the 1987 and 1989 ATP projects, Chrysalis Biotechnology (the company formed to commercialize the results) generated additional funding, including:

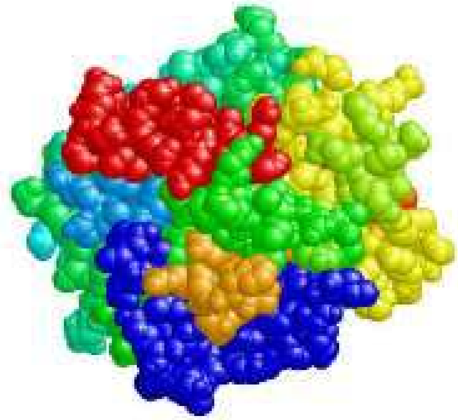
- $4 million for basic research from NIH and other government entities
- $6 million in equity funding from private investors
- Over $3 million in various SBIR grants
- Over $12 million in strategic license fees and development support.

In addition, the compound entered human clinical trials in 1998, and is currently being studied for a variety of human clinical applications.

Over the term of this grant, six faculty members, two staff researchers, eight graduate students and two undergraduate students participated in the research.



Vascular Tissue Repair



3D Computer Model of Human Thrombin

Graphics courtesy of Chrysalis BioTechnology

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Chrysails is a biopharmaceutical company developing new therapeutics to accelerate the healing of hard and soft tissue. The Company's lead product, Chrysalin®, is currently in Phase 3 human clinical trials for bone fracture healing, Phase 2 trials for chronic diabetic ulcers, and Phase 2 clinical trials for spine fusion.

Chrysalis received the Frost & Sullivan's Technology Innovation Award in Tissue Engineering. The award typically goes to a company that has demonstrated technological superiority within its industry. The award recognizes the ability of the company to successfully develop and introduce new technologies, formulate a well-designed product family, and make significant product performance contributions to the industry.

Chrysalis Bio-Technology Inc. was the first ever spin-out company for UTMB. Chrysalis had an exclusive worldwide license from UTMB for the technologies, and paid the University royalties based on product sales and sublicense fees, in addition to a significant amount of subcontracted research back to UTMB. UTMB also owned an equity share of Chrysalis.

In 2004 OrthoLogic Corporation [NASDAQ:OLGC] agreed to purchase Chrysalis for $34.5 million in a combination of stock and cash. OrthoLogic is funding the development of Chrysalin for a variety of orthopedic and non-orthopedic indications, and is currently conducting Phase 3 clinical trials for the acceleration of bone fracture healing.

LESSONS LEARNED

The success of the Chrysalin® technology had multiple positive effects for the State, including:

- The creation of over 20 high paying, high technology jobs in the Galveston region
- A significant financial return to the University, with the potential for future returns based on product sales
- Enhancement of the entrepreneurial experience of both the principals of Chrysalis as well as the University, hopefully fostering the development of future startups.

The research also enhanced the ability of the University's lab to provide an outlet for researchers to develop industry skills beyond what would normally be available to the students in a purely academic environment.

Case Study Profile: Peanut Processing

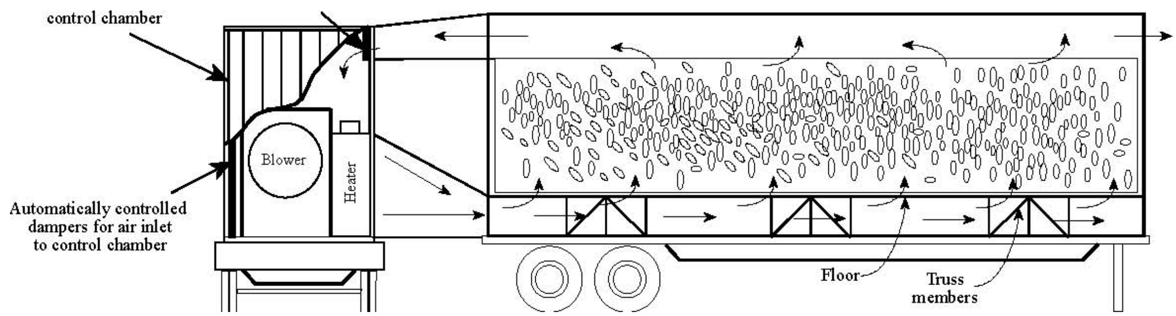
OVERVIEW

This is an example of a technology whose commercialization has had a significant economic impact on the state of Texas, but no direct benefit for the host university. **Dr. Atila Ertas'** 1997 TDT grant addressed the final steps in commercializing a new processing method for peanuts in dry climates, such as West Texas. The new Ertas process provided a four-fold increase in the quantity of peanuts that can be dried during a specified time period, moving Texas from third to second in U.S. peanut production. Five new plants were constructed in West Texas and 150 new full- and part-time jobs were created. In addition, the technology produced cost savings and substantial new sales for the industrial partner.

PROJECT BACKGROUND

The project dealt with a new process to dry peanuts in dry climates such as West Texas. Dr. Atila Ertas, College of Engineering, Texas Tech University, received a 1997 TDT grant titled, "Development of a Proper Peanut Drying Region for West Texas and Technology Transfer." The key goals were to establish the proper dry climate drying regime, develop a new process control algorithm, and implement and test the algorithm in an active peanut processing plant. The grant was preceded by a 1995 ATP grant that addressed the design, development, and construction of Dr. Ertas' new automated peanut processing system for dry climates.

Semi-trailer dryer
(Can also be used for peanut transportation & storage)



RESEARCH PROCESS

During the two-year grant period the test method was developed that led to establishing the proper drying regime for a West Texas-type climate. Whereas the old drying method was limited to about six tons of peanuts at a time, the new method could process about 24 tons. The new method also was more efficient, required less energy, and was quieter.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

For the period 1990-1996 prior to the introduction of Dr. Ertas' process, Texas peanut production averaged about 306,000 tons per year,[63] with West Texas and the Texas Panhandle accounting for over 70 percent of the production.[64] For the period 1997-2003, Texas peanut production averaged about 424,000 tons per year, and currently West Texas and the Texas Panhandle represent about 76 percent of the Texas production.[65] The increase in production was due to several pre- and post-harvest factors. Because of the nearly 40% increase in production from West Texas and Texas Panhandle, Texas moved from third to second in U.S. peanut production, behind Georgia.

The DeLeon Company, the industrial partner for this ATP project, was later acquired by the Golden Peanut Company. Through DeLeon's involvement with Texas Tech and Dr. Ertas, five successful West Texas processing plants were built in Lamesa, Seminole, Brownfield, Denver City, and Littlefield. The plants were a direct result of the new drying process and would not have been constructed without the new drying technology. These plants led to the creation of 150 new (full-time and part-time) jobs. Because of the seasonality of harvesting and drying, the number of full-time equivalent jobs is about 80. The annual payroll of these plants exceeds $1 million.

In an interview, Mr. Doyle Welch, former owner of the DeLeon Company, indicated that

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[63] http://www.utexas.edu/centers/nfic/natstat/data/1o002.pdf
[64] http://aggie-horticulture.tamu.edu/extension/cropbriefs/peanusts.html
[65] Phone interview with Dr. Dudley Smith, Texas Agricultural Experiment Station, Feb. 22, 2005

of the five DeLeon plants, three were capable of handling about 25,000 to 35,000 tons per year and two were smaller, with a capacity of between 12,000 to 15,000 tons per year. Application of the Ertas process, allowed DeLeon to build and equip their larger plants for about $2 to $2.5 million. According to Mr. Welch, costs to build the same capacity plants with the old style equipment would have been over $2 million more per location.

Besides the additional capital expenditures, the Ertas drying process provides significant operational advantages over the prior technology. The new drying process, besides allowing for significantly greater quantities to be dried, reduces overall operating costs by 70 percent, noise levels by 75 percent, and energy costs by 25 percent. In addition, the drying process produces better peanut quality.[66]

Mr. Welch also indicated there are 10 other currently operating, "Ertas-style" processing plants in West Texas and the Texas Panhandle, owned by other peanut companies. He said that there have been many plants in Georgia, Florida, and Alabama that have adapted this process, which is now the state-of-the-art method for drying peanuts in the US. Also, because of its clear superiority, the technology has since been adopted by processors in Australia and Argentina.

While the technology has clearly had a positive impact on the Texas economy, it has not directly benefited Texas Tech. At the time of the original research, a decision was made not to seek patent protection for the new drying process. As a result, the research technology was successfully transferred to the Texas peanut industry, as well as international producers, but has not generated licensing income for Texas Tech.

Dr. Ertas has indicated that former employees of DeLeon have formed a new company, Crop Docs, Inc. One of its business goals is to work with Texas Tech and Dr. Ertas to help commercialize a significantly improved, second-generation peanut processing approach. According to the PI, the new process is expected to offer even shorter drying times, larger volumes, and improved peanut quality.

LESSONS LEARNED

Dr. Ertas indicated that there were two major lessons that he learned from the technology transfer effort.

First, through DeLeon's and his own experience, he learned that if one is aggressive and stays open-minded, anything can happen, and nothing is impossible. He utilizes this lesson with his students constantly.

Second, he learned that an effort should always be made to develop intellectual property protection for a new technology. As he moves ahead with his new-generation processing approach, he is collaborating with Texas Tech to gain appropriate patent protection.

[66] "Totally Nuts", Vistas, Texas Tech Research, Fall 1999 Vol. 8 No. 1 Page 31

Dr Ertas' TDT grant research has provided very positive student impacts. As a direct result of the state grants, more than 30 undergraduate and five graduate students worked on the technology project. Also, the research effort has had an indirect educational impact. Dr. Ertas has written a capstone design book that features his peanut process design efforts.

Case Study Profile: Prototypes of New Lasers for the Telecom Industry

OVERVIEW

This project is an example of how a PI leveraged the research results from multiple ATP grants to help form a company, which was then able to participate as the industry partner for another successful TDT grant. **Dr. Gary Evans,** of Southern Methodist University, won a 2001 TDT grant that deals with the development of commercial prototypes of a new type laser for applications in the telecom industry. The enabling technology has the potential of significantly advancing the implementation of the 10 gigabit ethernet standard. Photodigm, a company formed by Dr. Evans and others in mid 2000, is the industrial partner. The product versions developed by the 2001 TDT funding are going through beta testing. In addition to the 2001 TDT grant's required matching funds, Photodigm provided SMU approximately $373,000 in cash and $896,000 of in-kind support. The grant research helped secure approximately $5 million of in-kind equipment and upgrades for SMU's clean room facility. The project has had a very positive student impact both in terms of attracting top quality students to SMU and improving course content.

PROJECT BACKGROUND

The project deals with the development of commercial prototypes of planar cavity grating-outcoupled surface-emitting (GSE) lasers for optical transmission applications in the telecom industry. Dr. Gary Evans, Southern Methodist University, Department of Electrical Engineering, School of Engineering, received a 2001 TDT grant titled, "Commercialization of Low-Cost Surface-Emitting Semiconductor Lasers at 1310 and 1550 nm" (see Figure 1). The goals of this technology transfer effort were to fully test GSE lasers that emit at 1310 and 1550 nm and finalize manufacturing process. The grant was preceded by two 1997 and 1999 ATP grants. The ATP grants helped Dr. Evans develop the working concepts that have led to the maturing of GSE lasers (see Figure 2) as a cost effective alternative photonics technology for current high-power optical telecom laser types. The ATP grants also encouraged Dr. Evans and others to found Photodigm in mid-2000.

RESEARCH PROCESS

During the two years covered by the 2001 TDT grant, Dr. Evans and his colleagues were able to perfect key aspects of their GSE laser technology, addressing several issues critical to its commercial potential. Most of the effort was concentrated on a commercially viable GSE laser emitting at 1310 nm. Part of the work was focused on assuring that the lasers could operate over a large temperature range, up to 85 degrees centigrade at the high end. Dr. Evans was able to resolve several subtleties of the grating out-coupler needed to meet marketplace requirements. Peak power was increased by a factor of five and the threshold current was decreased by a factor of 4, to below 20 milliamps. The product versions developed by the 2001 TDT funding are currently going through beta testing by potential customers.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The infrastructure of telecommunications and data communications networks is experiencing tremendous growth. As a result of the growth of the Internet, networks face the need to transmit an ever-increasing amount of data, faster and over long distances. The networks are focusing on photonics, the conversion of electrical data into light, and its capability to transmit data through fiber optic cable as the transmission medium. Of immediate concern is the need to develop a cost effective solution that will allow networks to upgrade to the 10 gigabit ethernet standard. Dr. Evans' GSE laser is an enabling technology that has the potential of significantly advancing the implementation of this critical standard.

This is an example of how a PI leveraged the research results from multiple ATP grants to help form a company, Photodigm (www.photodigm.com/), which was then able to participate as the industry partner for a successful TDT grant. SMU has established an agreement with Photodigm that provides the University a small equity share in Photodigm and sponsored research funding over several years to help support ongoing research.

State grants have helped generate over 15 new patent applications during 2002 and 2003. Three patents have been awarded in 2003. In November 2000, Photodigm received first round funding from Corning Innovation Ventures, Compass Technology Partners, Arkoma Venture Partners, and TriQuint Semiconductor. To date the company has received approximately $10 million in funding. Through Photodigm, Dr. Evans is currently beta testing the product versions of their 1310 nm GSE laser, developed by the 2001 TDT funding.

Based on the encouraging results of the 2001 grant, Dr. Evans received a 2003 TDT grant. The objective of the research effort is to increase the efficiency of the GSE laser and to demonstrate a new concept for very high speed (40 Gbps) modulation of GSE lasers.

Figure 1: Two-wavelength Cross Grating GSE Laser

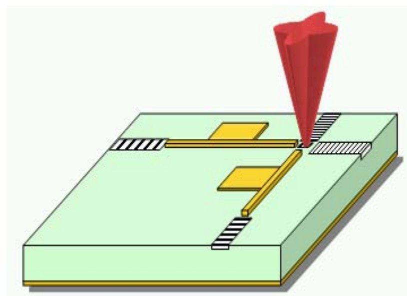
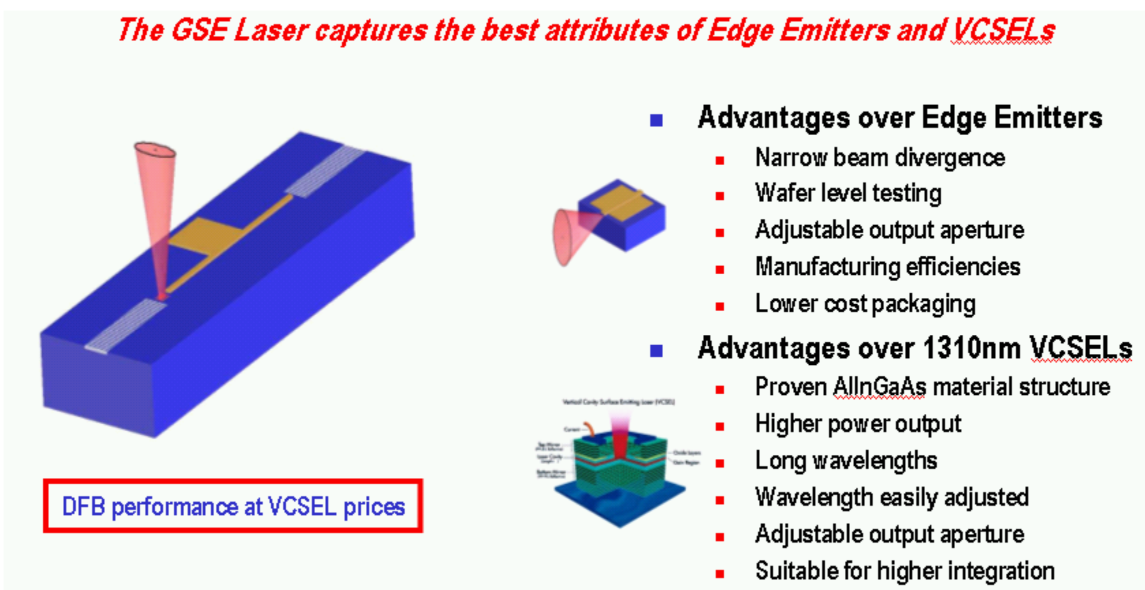


Figure 2



LESSONS LEARNED

In addition to the 2001 TDT grant's required matching funds, Photodigm provided SMU approximately $373,000 in cash and $896,000 in-kind support.

The TDT grant's research has helped secure approximately $1.5 million in SBIR funding by the U.S. Air Force, U.S. Army, Department of Energy and the National Science Foundation.

The grant research has been a factor in securing in-kind equipment and helped in obtaining support from TriQuint and others in establishing a new clean room facility at SMU valued at approximately $5 million.

Photodigm has additional research contracts with other SMU professors and departments. The contracts have included funding for projects in the College of Engineering and Department of Physics, totaling almost $100,000.

There are currently 14 Photodigm employees, including one of Dr. Evans' former students from the Texas grant funding. In their current fiscal year they expect revenues of approximately $800,000.

The TDT grant research has provided very positive student impacts, in several regards. The state program has provided funding to support between 4 and 5 extra students, which, in turn, has helped develop a critical mass for the research program attracting new students to SMU. The research is being or has been incorporated by Dr. Evans and other professors in at least five courses at SMU, including a new undergraduate research oriented course.

Dr. Evans emphasized two main lessons learned over the last few years from his involvement in the efforts to commercialize the enabling telecom technology. First, everything takes more time and costs more money than anticipated when developing a disruptive technology. The delay, in part, is due to a concerted effort by Dr. Evans and his colleagues to understand the needs of the market for the new, innovative technology and to integrate those requirements into the product design process on a real-time basis. Second, for a multidisciplinary research effort, as with the development of the GSE laser, one needs to be sensitive to interpersonal skills as well as the academic skills of possible candidates for the project team.

John Spencer, CEO of Photodigm, points out that it is extremely important for a technology based startup, in today's business climate, to generate revenue early. The importance begins with being alert for potential customers beyond the primary market. For Photodigm, the TDT research helped attract interest from government groups that has led to over a million dollars in SBIR support to augment venture funding.

Case Study Profile: Development of Respiratory Syncytial Virus Vaccine

OVERVIEW

Respiratory Syncytial Virus (RSV) infects 90,000 children and causes 4,500 deaths every year in the U.S. alone. No known effective vaccine is capable of combating the virus. A candidate vaccine for RSV was developed and a company, of which The University of Texas Southwestern Medical Center at Dallas is part owner, has started to commercialize the potential life-saving technology.

PROJECT BACKGROUND

Through research funded by a previous ATP grant a new method for creating vaccines was invented. The invention, "expression library immunization" (ELI), is a genetic immunization approach to discover new vaccine candidates. Although several commercial research contracts applied ELI to bacterial and parasitic pathogens, and DARPA had funded the development of vaccines against biological warfare agents, none had employed a different strategy that the inventors felt could be used to improve existing or to create new vaccines. Commercial interest in using the strategy to create a vaccine for RSV led to a Technology Development & Transfer (TDT) grant was awarded in October of 1997. The project's PI was **Dr. Stephen Albert Johnston,** a professor and the director of The Center for Biomedical Inventions (CBI) at the University of Texas Southwestern Medical Center at Dallas.

RESEARCH PROCESS

Virion Systems Inc., the industrial sponsor, focuses on vaccines, specifically those for respiratory related infections in children. At the time the project started, Virion was in Phase 1 clinical trials of their own RSV vaccine. Researchers at Southwestern worked on implementing the new strategy of ELI techniques to the RSV. Virion provided the cotton rats and the facilities to house and observe the 300 rats needed to conduct 4 rounds of tests. It only took 3 rounds of testing to isolate the pieces of the RSV DNA that could be useful as a vaccine.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The goal from the beginning was to start a company in the Dallas, Texas area. The PI and Southwestern personnel sought to establish the Center for Biomedical Inventions (CBI) at Southwestern. The long term purpose of the center was to invent biomedical technologies and provide a focal point for biomedical expertise in the DFW region. The concentration of experts was to be leveraged to keep the startup company and others in Dallas instead of locating on the east or west coasts.

The 'leverage' worked and, based on the Expression Library Immunization and Linear Expression Element inventions, a new venture backed company named ELIance Biotechnology Inc. was formed by Southwestern in Dallas. The company was formed with ELI as its core technology. Its purpose was to continue the collaborative efforts with Virion. The goal was to continue the efforts to refine the isolation of RSV DNA for the creation of a vaccine and to apply the same research techniques to isolate DNA pieces for the development other vaccines. As part of the agreement to receive venture funding one of the researchers, Dr. Kathy Sykes, took a leave of absence from Southwestern to continue the work at ELIance. ELIance was the first startup company based on a technology out of Southwestern that was formed in and stayed in Texas.

As part of the TDT grant, the industrial sponsorship agreement stated that any Eliance patents that related to an RSV gene fragment would be jointly owned by Virion, the industrial sponsor, and Southwestern, with Virion having exclusive licensing rights to the technology. The agreement also gave Southwestern 50% of all income derived from the technology developed under the grant.

At the beginning of the project Virion was slow in providing the required reagents to Southwestern. Consequently, Southwestern contributed significantly more effort to the research than did Virion. The uneven distribution of effort led to a renegotiation of the agreement thereby giving Southwestern a 75/25 split rather than equal shares. To date, no licensing revenues have been received by Southwestern from Virion.

During ELIances' process of securing its second round of funding, the CEO of MacroGenics (a newly started company backed by InterWest Partners of San Diego, CA) was asked to evaluate ELIance and its technology. The recommendation was to grant the round of funding, $12 million, and to merge ELIance with MacroGenics. After the merger $10 million from two different grants was also awarded, one a SBIR and the other from National Institute of Allergy and Infectious Diseases (NIAID).

Of the Southwestern researchers and students who worked on the project, three undergraduate students, one postdoctoral and one technician from Center for Biomedical Inventions (CBI) are working at MacroGenics. All of them are working on high throughput genomics either in molecular biology, computation or robotics. Dr. Sykes completed the required knowledge transition and returned to CBI in the summer of 2004 as an Assistant Professor.

Because of the investor-imposed requirements to bring a product to market quickly, MacroGenics has stopped work on the very difficult RSV vaccine and is working to develop more commercially viable technologies. MacroGenics shifted its emphasis to therapeutic products rather than vaccine discovery. It has three divisions, in Rockville, MD, Dallas, TX and Seattle, WA. The Rockville and Dallas locations each have 21 employees. A second round of venture funding is imminent. Although approximately

$200,000 in licensing fees were generated for the core technology, most of Southwestern's interest in MacroGenics is in equity and like the Virion relationship, no licensing revenues have been earned by Southwestern.

LESSONS LEARNED

The success of the commercial venture can be attributed to several key decisions made prior to starting the project. The core intellectual property, ELI, was protected by a patent before the PI applied for the grant to begin commercialization. Although negotiated research contracts were signed with several companies to validate the technology and keep the operation funded, the agreements did not obligate the core IP. The agreement thus allowed for the possibility of a start-up company founded on the IP. Several attempts were made to find a company interested in working to apply a new strategy to the existing ELI to create a new vaccine. The PI and Southwestern did not attempt to commercialize the technology in isolation.

When Virion agreed to be an industrial partner, the PI moved forward by applying for the TDT grant to begin creating a commercially viable vaccine. Because of the clearly defined agreement the University had with Virion, it was possible to renegotiate the revenue arrangement when it became apparent that Southwestern had done a larger portion of the work than Virion.

The formation of the Center for Biomedical Inventions achieved its initial purpose of being a center of expertise, which would maintain the startup company ELIance located in the region. Future inventions created in the Center would be the genesis for additional startup companies in the DFW region.

Case Study Profile: Commercially Viable Production of Functionalized Fullerene Nanotubes

OVERVIEW

Since **Professor Rick Smalley's** discovery of fullerenes at Rice University in 1985, the potential has not been realized because of the difficulty of production.[67] The soccer ball shape of the C_{60} molecule led to its name "buckminsterfullerene" in honor of Buckminster Fuller and his work in geodesic domes. The most commercially promising fullerene is the carbon nanotube, which is a cylinder of bonded carbon atoms approximately one nanometer (one billionth of a meter) in diameter, and typically hundreds to thousands of nanometers long.

[67] Professor Smalley, Professor Robert F. Curl, Jr. of Rice University, and Sir Harold W. Kroto of the University of Sussex were awarded the 1996 Nobel Prize in Chemistry for their discovery of fullerenes.

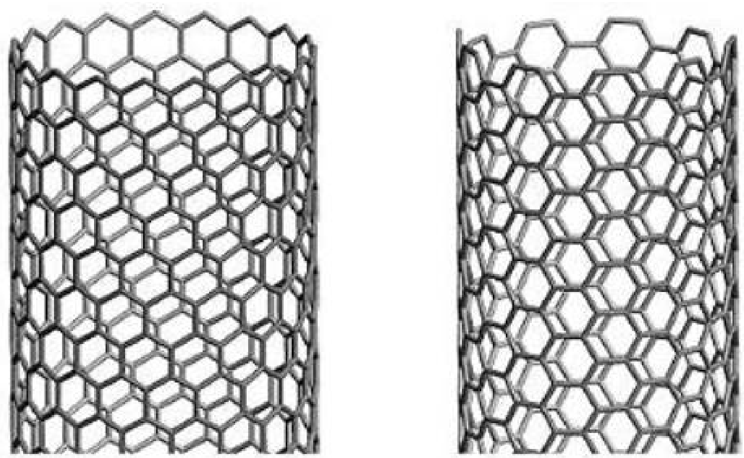
The goal, based on building blocks provided by three consecutive ATP grants to Professor Smalley, was to develop a process to produce single-walled nanotubes (SWNT), affectionately called buckytubes, in sufficient quantities that nanotechnology researchers could focus their efforts on the use and implementation of SWNT, not on their creation or manufacture. What was learned and improved upon since the initial 1995 ATP grant led to the formation of a company, Carbon Nanotechnologies Incorporated (CNI), in Houston, Texas. According to the company Web site, it is "…the preeminent world producer of buckytubes. The company can provide buckytubes in many different grades to accommodate customer-specific needs." The company currently owns, or has licensed, more than 100 patents and has more than 450 customers.

PROJECT BACKGROUND

Buckytubes, being pure carbon objects, contain several highly desirable properties. They have a tensile strength 100 times that of steel, greater than any other known material at a fourth the weight, and thermal conductivity five times higher than copper. The properties are leading to revolutionary advances in material composites, superconductivity, electrochemistry, batteries, fuel cells, thermal barrier coatings, flat-panel displays and molecular electronics. However, the lack of availability of SWNT has hindered significant advancements in potential applications. While there were two existing productions methods used by suppliers of nanotubes material, innovations were limited to multi-walled nanotubes (MWNT). MWNT uses were limited by defects and imperfections inherent in the production methods. For the potential that buckytubes offered to be realized, a process had to be developed that was capable of producing more than 100 grams of SWNT per day. Dr. Richard Smalley and Carbon Nanotechnologies are developing commercially viable SWNT production processes.

RESEARCH PROCESS

Based on the laser vaporization ovens used in fullerene production, the team initially developed a technique that produced around 0.5 gram of SWNT per day. To achieve the 100 grams per day goal, an oven was perfected that could be run unattended twenty-four hours per day. The next step was development of a higher yielding process (high-pressure CO – HiPco) that produces a "ready to use" SWNT, which requires no additional purification for some applications. The new process holds the production promise of scalability to tons per day—up significantly from 200 grams per day. Not unexpectedly, the process drew considerable commercial interest as increased availability of SWNT could launch new industries and change existing ones. The ATP funding helped Professor Smalley and his students develop solutions to the chemical engineering challenges of the HiPco process to meet the requirements for commercial production.



Buckytube Structures

Images courtesy of Carbon Nanotechnologies, Inc.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Following the initial ATP grant, a non-profit organization, Tubes@Rice, was formed to supply nearly 200 grams of SWNT to the worldwide research community. Simultaneously, commercial interest in SWNT was growing rapidly, driving the need to increase production and make buckytubes available to commercial enterprises.

In early 2000, Carbon Nanotechnologies, Inc. (CNI), was formed in Houston to provide a commercial source for carbon nanotubes. CNI licensed from Rice all of the rights to the intellectual property that Professor Smalley and his group had developed. Under the licensing arrangement, Rice took ownership of equity in CNI and receives royalties on products sold by the company. Dr. Smalley and Dr. Ken Smith, colleagues in research and development of carbon nanotechnology at Rice, are two of the founders of CNI. Another co-founder, Dr. Bob Grower, the president and CEO, has 36 years experience in the chemical industry with managerial experience at ARCO Chemical, Atlantic Richfield and Lyondell Petrochemical. Four current vice presidents of the company each have more than twenty-five years of experience in R&D at chemical and petrochemical companies.

CNI currently has 30 employees, 10 contractors and 10 consultants who have worked closely with the researchers at Rice to complete the development of the first two generations of prototype reactors. CNI purchased the second generation reactor, Mark Two, from Rice and sold SWNT while additional pilot plant scale reactors were built. In April 2001 CNI announced the acquisition of $15 million in angel investor funding. CNI now has multiple reactors for production of small-diameter carbon nanotubes, the largest of which is currently being brought on line and has a capacity of 100 lbs. of nanotube production per day. CNI has expanded to include approximately 7,500 feet^2 of space in the Houston area - 1,500 for operations and 6,000 for manufacturing. The National

Institute of Standards and Technology (NIST) granted a joint award of $3.6 million to CNI, Motorola, Inc. and Johnson Matthey Fuel Cells, Inc. in September 2004. The focus of the ATP grant is to develop SWNT electrodes to be used in micro-fuel cells.

DuPont Central Research & Development (CR&D) and Entegris Inc. are two key customers of CNI products. Since January 2002 DuPont has been developing a production process to use SWNT in flat panel displays. In mid-2004 Entegris signed an agreement to develop applications of SWNT in semiconductors, data storage devices, pharmaceuticals and fuel cells. Kellogg Brown & Root (KBR) has had an engineering service agreement to the pilot and production plants where CNI has produced SWNT products since October of 2001. To expand its presence in Asia, CNI signed an exclusive marketing agreement with Sumitomo Corp. of Japan in 2002.

LESSONS LEARNED

Using a non-profit organization to supply the research community with small quantities of a new material can speed the emergence of demand from private firms to produce new or improved products based on the material. Tubes@Rice drew commercial interest and international attention to the PI's research at Rice's Center for Nanoscale Science and Technology.

CNI's licensing of patents enabled the company to continue development of a commercial scale production system without the hindrances of potential patent infringement problems. The licensing strategy allowed the company to continue developing a viable commercial enterprise in a revolutionary new material while continuing to collaborate with the Rice researchers. Dr. Smalley is Chairman of the Board of CNI and his laboratory at Rice continues to lead the world in developing advanced methods for nanotube production. He is now developing a process for making nanotubes that are all exactly the same type and diameter, and it is anticipated that CNI will commercialize the new production process.

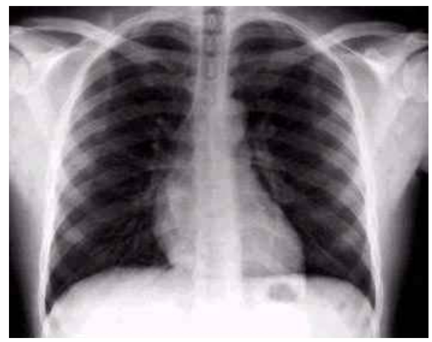
Case Study Profile: Filtered Raman Spectrometer

OVERVIEW

Drs. Philip Varghese and **Manfred Fink** at the University of Texas at Austin have patented and prototyped the Filtered Raman Spectrometer, a device that can detect human disease without physical contact with the patient. The cost and time savings due to this novel device could expand the currently limited marketability to doctors and hospitals, bringing substantial royalties back to a Texas university while saving many lives. The discovery has resulted in an international collaboration and spawned an as-yet-unnamed new U.S. company to market the new technology pending FDA approval.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Philip Varghese, professor of aerospace engineering and engineering mechanics and Director for the Center for Aeromechanics Research at the University of Texas at Austin, won an ATP grant in 1995 to explore a novel Raman diagnostic technique using diode laser arrays to monitor air pollutants in stack gases. In 1999, after receiving a second ATP grant, Dr. Varghese teamed with Dr. Manfred Fink, professor of physics at UT Austin and an international authority on atomic and molecular physics. They discovered a multidisciplinary spin-off application, Filtered Raman Spectrometry, important to medical diagnostics. By using a tunable laser to excite inelastic light scattering, a novel modification to the existing technique of Raman Spectrometry was developed that can be used in medical applications. If FDA clinical trials confirm its efficacy, commercialization will occur.



The patented technology allows the detection of certain human diseases without physical contact with the patient by monitoring the concentration of carbon-13 dioxide molecules in the patient's breath. Specific carbon-13 labeled compounds can be ingested to focus on different organs and diseases. If the test is positive, the body's natural metabolism will release small but detectable amounts of the carbon-13 dioxide molecules in the patient's breath that are measured by the device to diagnose the disease. Among the advantages over similar technologies, the Raman Spectrometer can reduce result-turnover time from days to less than 60 minutes, due to the non-invasive outpatient nature of the test. The faster results can, for the first time ever, potentially save 16,400 newborns each year that die from lactose sensitivity. The device can diagnose the known carcinogen and ulcer-causing bacterium Helicobacter pylori. Similarly, an extension into nitrogen-15 isotope detection can be used to diagnose some cancers and the technology can also promote more efficient health care by monitoring a patient's reaction to medication, allowing for more efficient dosing and leading to quicker patient recovery.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

An Oklahoma-based company (OMEDtech) has partnered with UT Austin to commercialize the project and is currently raising money to incubate a new company. OMEDtech has paid for the 2004 patent and the PIs have produced a prototype with a significantly lower manufacturing cost relative to competing models. Competitive testing devices include high-resolution mass spectrometers, which are used for general tests and cost nearly $200,000, pricing it out of many markets. The Filtered Raman Spectrometer, a much smaller and faster device, specializes in carbon-13 dioxide detection and will cost about one-sixth of the price, significantly enlarging the market of end users.

The next phase of commercialization will involve human clinical studies required for FDA approval. The team's consultations with experts have determined the FDA testing should proceed smoothly because the novelty is in the detection scheme and not the compounds administered to the patients, which are already FDA approved. OMEDtech is assisting in raising the capital necessary to administer the FDA trials. Once federal approval is obtained, the Filtered Raman Spectrometer will have access to a forty-percent world market share due to UT Austin's U.S. patents. The new company will have to license breath tests from other companies and may result in new industrial partnerships fueling biomedical industry growth.

LESSONS LEARNED

As a result of the ATP grants, a highly promising medical diagnostic device has been developed and patented. Through the successful efforts of UT Austin's Technology Transfer Office, an Oklahoma company will work closely with the university to market the device once it is FDA approved. Moreover, spin-off projects have brought an additional $800,000 in Texas-based research from the National Science Foundation and the Army Research Office.

The ten student researchers supported during the project have learned new skills and developed new expertise as a result of their "hands on" work. Many of the graduates have left Texas to pursue careers; one interned with Wagner Analysen Technik in Germany as a result of the industrial connections established under the ATP grants. Another student won first place in the 1995 American Institute of Aeronautics and Astronautics Regional Competition for his paper describing the preliminary work on a laser velocimeter.

Case Study Profile: Pesticide-Detection Systems and Appropriate Detoxifying Bioreactors

OVERVIEW

As a result of his 1987 Advanced Technology Program (ATP) project titled "Development of Pesticide-Detection Systems and Appropriate Detoxifying Bioreactors," **Dr. James R. Wild** from Texas A&M University has received over $3,850,000 in follow-on research funding and produced over forty research publications. Additionally, one of the postdoctoral scientists who worked on the project, Dr. Steven McDaniel, commercialized the research by starting a company, Reactive Surfaces LTD of Austin, Texas. The ATP project also allowed for advances in the field of destruction of chemical warfare agents, and has facilitated the training of over twenty students and five post-doctoral fellows to date.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Wild became interested in this area of research because the detection and detoxifying of agricultural pesticides had become significant problems, common to many areas around the world. The focus of the project was to develop an enzymatic system that could be utilized for the detection and quantification of commonly used insecticides. Additionally, Dr. Wild intended to initiate the application of a family of related enzymes to practical technologies for the detoxification of neurotoxic agricultural pesticides.

The basic research began in 1984 and was oriented toward the cloning and biochemical characterization of a stable enzyme that was able to degrade a wide spectrum of organophosphate neurotoxins. Dr. Wild's research group discovered that the enzyme OPH (organophosphorous hydrolase) was also able to degrade type G and type V chemical warfare agents. New opportunities opened in the application of the enzyme technology for the detection and remediation of chemical neurotoxins. Modified forms of the original enzyme are now being introduced into several applications in the destruction of United States Department of Defense (DOD) chemical warfare stockpiles, for protection of military personnel around the world, and ultimately in anti-terrorist detection and decontamination.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The doctoral student/post-doctoral fellow in Dr. Wild's laboratory, Dr. Steven McDaniel, who discovered the gene for OPH in 1984 and received his Ph.D. in 1985, subsequently received his JD from the University of Houston Law School. He is the founding CEO of a new start-up company Reactive Surfaces, Limited (RSL). Additionally, Dr. Wild has worked with three other companies (LynnTech, LTD of College Station, Texas; Prodigene, INC. of College Station; and Agentase, INC of Pittsburgh, Pennsylvania). He has also received support from various private and federally supported programs - Small Business Innovation Research (SBIR's), Small Business Technology Transfer (STTR's) and Broad Agency Agreements (BAA) from the DOD. Dr. Wild also stated that the university administration technology transfer program played little to no role in the commercialization process; attempts to seek patent protection for several of the applications were not pursued because the university did not wish to assume the patent expenses.

As a result of this project, Dr. Wild received additional research funding totaling $3,850,000; he said that this would not have been possible had it not been for the initial ATP grant that allowed him to begin his research. The following is a partial list of the follow-on funding received by Dr. Wild as a result of the ATP Project:

$2,500,000 – Department of Defense (SBIR, STTR, BAA) from DOD
$400,000 – Department of Energy (PNNL and Sandia, Livermore)
$350,000 – National Science Foundation
$300,000 – Industrial Funding: Reactive Surfaces Ltd, Austin TX

$50,000 – State Funding – Texas Agriculture Experiment Station

Although he received a substantial amount of follow-on research funding, Dr. Wild commented that he has found it difficult to obtain transitional funds to move from the basic science studies to the "on-the-shelf" technologies. Without steady support from any one source, Dr. Wild has been forced to use multiple funding agencies, including NSF and the Army Research Office (ARO), multiple university research initiatives, and SBIR-STTR programs. Consequently, more of his time has been spent on arranging funding than Dr. Wild feels was desirable. Overall, the commercial support from Dr. Steven McDaniel was critical in the developmental and commercialization processes that resulted from the ATP project. RSL has supported most of the commercialization aspects of the project, and significant support has come from the Telemedicine and Advanced Technology Research Center (TATRC/MRMC), Fort Dietrick, Maryland.

In Dr. Wild's opinion, the project was critical in attracting outstanding graduate students and post-doctoral fellows who have become new faculty members at Auburn University and Brigham Young University, a senior Project Manager at the Department of Energy (DOE) Pacific Northwest National Laboratory (PNNL) in Richland, Washington, and a senior scientist at U.S. Army Research Development Center (USAMREDC) in Edgewood, Maryland. To date, at least fifteen Ph.D. students and six post-doctoral students who have worked on the project are employed in federal/state positions in related fields.

LESSONS LEARNED

The ATP project initiated a wide series of studies with the enzyme OPH which has to date been made available to university, commercial, and federal laboratories (including DOD, USDA, and DOE research groups) without a license. In certain instances, Dr. Wild made an intentional decision to side step the exclusivity of the patenting process and make certain aspects of the technology widely available. Patents are pending on certain applications. Additionally, as a result of the ATP project, RSL was founded by Dr. McDaniel in April, 2002. Also, over the past three years, research on chemical warfare agents has increased and there is an increasing emphasis on chemical decontamination and prevention of bio-chemical terrorism.

Dr. Wild commented that in his field, modern research requires quite expensive and sophisticated instrumentation. Therefore, he believes the ATP program should establish an equipment matching fund to make available the funds necessary for purchasing instruments. Under his plan, individual universities would match the amount received from the ATP fund.

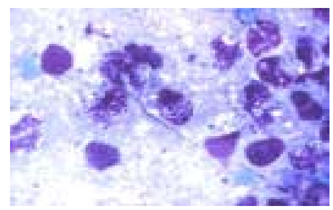
GROUP 3: PROMISING COMMERCIALIZATION OPPORTUNITIES

Group 3 consists of projects that are on the verge of generating significant follow-on funding, establishing commercial ties with private firms, or have patents pending on their technologies. Some are pursuing many commercial leads or different strategies simultaneously. Some are working in areas at the very limits of scientific knowledge. While no guarantees exist, the long-term commercialization potential appears significant.

Case Study Profile: Bovine Brucellosis Vaccine

OVERVIEW

Brucellosis



Source: ces.purdue.edu

Dr. Leslie Garry Adams and his collaborators have developed an improved vaccine and two diagnostic tests for Bovine Brucellosis through Texas A&M University. The technologies have been licensed, revenues have been generated, and products are now being tested for implementation internationally. The last in a series of three ATP grants has led to tens of millions of dollars in spin-off research in Texas, recognition from the National Center of Excellence, and was the primary motivation for the establishment of the Department of Homeland Security's "National Center for Foreign Animal and Zoonotic Disease Defense" program.

PROJECT BACKGROUND AND RESEARCH PROCESS

Despite the vaccination of 10 million cattle annually, brucellosis continues to cause losses exceeding $138 million each year in the U.S., approximately 10% of which occurs in Texas. **Dr. Garry Leslie Adams**, associate dean for research and graduate studies, professor of veterinary pathology, and a member of the faculty of the College of Veterinary Medicine at Texas A&M University, was awarded an ATP grant in 1989 to develop a live recombinant vaccine for bovine brucellosis. The technology would reduce the number of cattle that must be destroyed due to false positive results for the disease and save Texas industry $50 million over the next decade.

Dr. Adams has been actively engaged in bio-defense and infectious disease research for the last three decades. He began his work on the brucellosis vaccine in 1985, sponsored by the first of three ATP grants. His research produced positive results and has led to follow-on ATP grants in 1987 and 1989. In addition, Dr. Adams and his collaborators have received over $10 million from USDA grants, NIH grants, and private enterprise grants such as Pittman Moore, which awarded $250,000 for additional testing. The research has led to three patents and numerous material transfer agreements with universities and organizations on three continents.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Texas A&M University has earned over $200,000 in licensing revenue to date. Pittman Moore, a biologics firm in Kansas City, essentially reimbursed the cost of the patents with $100,000 in royalties to the university. The license was then transferred to Diagnostics and Biologics Technologies in San Antonio, Texas, and an additional $100,000 in licensing fees was paid. After D.B.T. went bankrupt due to investor pull-outs, the licensing rights were transferred back to Texas A&M University.

The research has also led to two additional patents. Aside from the vaccine, two diagnostic tests were developed and patented by the team of scientists. “Brutech” was licensed to Diagnostics and Biologics Technologies for $50,000 with an additional $50,000 for further research. The technology was used by the USDA for 2-3 years until a newer technology emerged. The other diagnostic test was licensed to Diagnostics and Biologics Technologies for $12,000 and was marketed until D.B.T. filed for bankruptcy. Further developed for bio-defense was ongoing through the Department of Homeland Security.

Texas A&M University has since obtained material transfer agreements with the University of Pretoria in South Africa through the Onderstepoort Veterinary Preparation Corporation, the National Autonomous University of Mexico in Mexico City, and the Russian Regional Center for Toxicology and Hygienic Regulation of Bio-preparations through the Ministry of Health of the Russian Federation in Serpukhov, Moscow, Russia. These three organizations are currently testing the vaccine for efficacy. If the vaccine is implemented and distributed, South Africa would consume 10,000,000 doses per year and Mexico/South America would consume 20,000,000 doses per year. With one dose of the vaccine costing approximately $1, negotiations for royalty payments are ongoing and will most likely result in a declining royalty scale. According to Dr. Adams, the Mexico/South America tests have the highest probability for success.

LESSONS LEARNED

The most important aspect of the ATP grant was bringing together the group of scientists involved from universities across the nation including Columbia, Rutgers, Oregon State, and Baylor. The ATP grants totaling $1.3 million, through the group of scientists, has led to $58 million in additional research at the University of Texas Medical Branch in Galveston. The National Center of Excellence has returned $6 million to Texas A&M University over 5 years and the grant was also the primary factor in $18 million Dept. of Homeland Security’s “National Center for Foreign Animal and Zoonotic Disease Defense” program.

ATP funding has led to three patents, one vaccine, two diagnostic tests, as well as millions in federal research funds and programs being brought to the state. More importantly, it has led to additional human capital for Texas. Since research began in 1985, 20 PhDs have been educated through grant funding and 75% are now conducting their own academic research. More directly, the 1989 grant supported 10 undergraduates and 4 graduate students. The full economic impact of this project will take years to play out but has already lead to more creative ideas, products, and revenues for the state of Texas.

Case Study Profile: Characterization of the Human Cardiac Stem Cell

OVERVIEW

Dr. Daniel Garry's 2001 ATP grant is directed at the characterization of the human cardiac stem cell population. Previously a 1999 ATP grant dealing with skeletal muscle stem cells was awarded. The ATP projects helped the PI and others secure a $30 million grant from Donald W. Reynolds Foundation. The ATP projects helped the PI obtain two NIH awards, worth approximately $2 million. The project has had a very positive impact for the students involved in the technology transfer effort. The experiences led to a number of prestigious awards.

PROJECT BACKGROUND

Dr. Daniel Garry, UT Southwestern Medical Center, Departments of Internal Medicine and Molecular Biology, received a 2001 ATP grant titled, “Molecular Characterization of Human Cardiac Stem Cells.” The goals were to isolate the stem cell population, obtain a comprehensive molecular expression profile, and determine the plasticity of this cell population when placed in a permissive environment. The grant was preceded by a 1999 ATP grant that addressed the isolation and genetic engineering of skeletal muscle stem cells.

RESEARCH PROCESS

During the two years funded by the 2001 ATP grant, Dr. Garry and his colleagues successfully explored the three main goals of the research project. During the first year they were able to isolate the human cardiac stem cell population, using flow cytometry (see Figure 1). They first isolated the cardiac stem cell population of mice, and then developed an RNA amplification strategy that enabled amplification of RNA by approximately one million fold. The strategy was then utilized to evaluate the molecular program of the cardiac stem cells during development and from the adult transplanted human heart over a period of time. Finally, Dr. Garry successfully evaluated the plasticity of the stem cells, confirming they were capable of differentiating special heart muscle cells, called cardiomyocytes, and of forming the various lineages of blood.

TECHNOLOGY TRANSFER/COMMERCIAZLIATION RESULTS

The case study exemplifies how successful ATP projects can advance a cutting edge area of research with significant commercial potential. Despite current pharmacological and whole organ transplantation strategies, advanced heart failure remains a common and deadly disease. Recent studies challenge preexisting notions regarding cardiac repair and suggest that the heart is capable of limited regeneration through the activation of resident cardiac stem cells or the recruitment of extracardiac stem cell populations. The ATP project was a key step in validating the hypothesis and its associated health and commercial potential.

Dr. Garry has been in close communication with the UT Southwestern Medical Center's Office of Technology Development concerning the most appropriate IP strategy to pursue for the technology. The plan is, over the next few months, to finalize work needed to establish a cardiac clonal cell line and then make application for patent protection. Some initial discussions have been conducted with at least one company concerning the potential initial commercial path for the technology.

LESSONS LEARNED

Together with several other projects, the ATP projects led to a five-year, $30 million award to UT Southwestern Medical Center from the Reynolds Foundation. UT Southwestern is one of the Foundation's four centers across the country. The ATP projects also helped Dr. Garry obtain two NIH awards, worth approximately $2 million.

ATP funding came at a critical time for Dr. Garry's research and UT Southwestern's stem cell program. The grants allowed for acquisition of important laboratory infrastructure and have been a key element in the establishment of a nationally recognized stem cell effort at UT Southwestern.

The PI now directs a monthly stem cell seminar that the ATP research has helped to make possible. The seminar attracts a wide range of participants including undergraduates, graduate students, and faculty.

Several students and postdoctoral fellows participated in the studies related to the specific aims of the grant. The trainees received a number of prestigious awards, including:

- David R. Redden Award, given to the outstanding student in the biological sciences at University of North Texas
- AstraZeneca Young Investigator Award
- Cardiovascular Research Award from the annual Cardiovascular Symposium held

at UT Southwestern Medical Center.

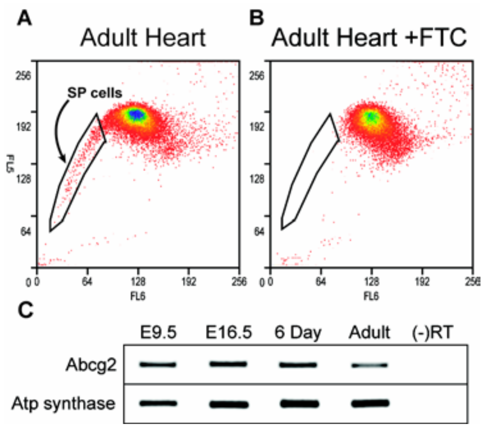


Figure 1: Laboratory evidence supporting existence of cardiac stem cell population. (A) Cardiac stem cells (SP) are shown in cardiac tissue using dye and flow cytometry. (B) The stem cells disappear when tissue is incubated with stem cell inhibitor. (C) Illustrates RNA expression of stem cells in the developing heart and decreased expression in the adult heart.

Dr. Garry organizes and directs the Cardiovascular Symposium that focuses on emerging technologies in the cardiovascular field. The symposium highlights the work of students as they present their scientific studies in a poster competition.

Case Study Profile: Human Skin Equivalents

OVERVIEW

Dr. Robert Gracy, winner of several ATP grants, and **Dr. Dan Dimitrijevich** have successfully developed a patented procedure for growing a human skin and corneal equivalent that has many applications across pharmaceutical, biotech, cosmetic, and other consumer industries. The technology has been licensed to three companies, one of which is publicly traded on the NASDAQ. The ATP projects have helped transform basic research into application and commercialization of a successful product that has launched a new company and attracted an existing pharmaceutical company to Texas technology.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Robert Gracy, Associate Vice President for Research and Biotechnology and Professor of Molecular Biology and Immunology at the University of North Texas (UNT) Health Science Center, and Dr. Dan Dimitrijevich, Associate Research Professor at the

UNT Health Science Center's Department of Integrative Physiology, realized the need for in vitro alternatives to animal testing across many science and consumer industries. Animal models have many drawbacks for initial product testing, including potentially invalid extrapolation to humans, high cost, and circumstances that are impossible to model in animals. Trans-dermal delivery patches have many advantages over oral doses and are believed to be a key means for future drug delivery.

Beginning with 1987 and 1991 ATP grants, the team successfully developed methods for growing fully differentiating human skin and human corneal equivalents. Originally, the research aimed to aid wound healing in the elderly, but the PIs soon realized the tissue equivalents could also be used for transplantation, tissue engineering, and evaluation of new drugs and trans-dermal delivery patches (e.g. nicotine patch) without animal testing. The 1993 ATP grant successfully developed methods to validate and automate the accomplishments from the previous ATP projects and led to a $239,000 NASA grant in which Dr. Dimitrijevich and the team discovered large sheets of tissue can be grown efficiently and economically in microgravity.

As a direct result of the ATP funding, additional funding has been received through the National Science Foundation ($164,189) and sponsored research agreements with Bank One ($15,000) and Lescarden, Inc. ($38,728). The technology has applications ranging from stem cell research to cancer and cell therapy as well as benefits for the elderly and diabetics.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Cells of human tissue are used to seed a "scaffold," which is then bathed with growth factors, causing the cells to produce three-dimensional tissue.

The University of North Texas' Technology Transfer Office has successfully commercialized the research. As a result of the NASA grant, several patents for the method and apparatus in using microgravity conditions to culture the human skin equivalent (HSE) have been obtained and funded through a partnership with Dr. Dimitrijevich and Synthecon Inc., the world's leading manufacturer of 3-dimensional tissue culture systems, based in Houston, Texas. Synthecon Inc. was recognized as one of Houston's fastest-growing technology companies, being named to the 2003 "Fast Tech Fifty." Some of its success can be considered an indirect result of the ATP grants as Dr. Gracy's team tested the company's Rotating Wall Vessel Cell Culture Systems. As a consequence, two new patented hardware configurations were developed for Synthecon. Additional licensing agreements and fees continue to be negotiated, most recently to use the materials for laboratory diagnostics.

NexMed Laboratories Inc., a publicly traded company on the NASDAQ with a current market value of just over $60 million, has also obtained a license to evaluate the trans-dermal delivery system; fees are being negotiated. Ongoing clinical trials research with NexMed Laboratories, Inc. of Robbinsville, New Jersey has continued to bring more out-of-state funding to Texas-based research as a result of the ATP grant. Sponsored research projects have included Alcon Laboratories, Inc. of Fort Worth, Texas, and Johnson & Johnson Medical, Inc. of Arlington, Texas. Alcon Laboratories has continually contracted with Dr. Dimitrijevich for the growth and supply of eye tissue equivalents since the 1991 ATP grant, while Dr. Gracy trained two Alcon employees as doctoral students in aging of lens and the effect of aging on cornea drug delivery.

The human skin equivalent has been an important contribution to the emerging field of tissue engineering. The co-inventor of the technology, Dr. Dimitrijevich, has three associated sponsored research agreements providing an additional $1,850,000 for Texas-based research, and a new company is in the early stages of development. He has patented an engineered membrane, a device to prevent post-surgical adhesions, as a result of the knowledge gained through the 1987 and 1991 ATP grants. The membrane has led to an additional patent and spurred the 2003 formation of Global Medical Research, LLC in Florida, which is actively seeking venture capital to further market the technology.

LESSONS LEARNED

The technology developed independently and collaboratively under the ATP grants has resulted in several commercial partnerships, both in and out of Texas. Through the efforts of the technology transfer office at UNT, the Synthecon and Alcon partnerships have successfully strengthened Texas-based entrepreneurial growth, while out-of-state partnerships with NexMed and Global Medical Research will bring additional revenue in the near future. Similarly, two students who received their doctorates working on the project now work for Alcon Laboratories in Ft. Worth, Texas, as a result of the ATP grants. Other companies have picked up the research as well, adding to intellectual property and spurring competitive economic development across the bio-technology sector.

GROUP 4: PARTNERSHIPS

Group 4 consists of case studies that illustrate the benefits that can be generated when PIs or their labs establish close working relationships either with companies or other researchers. The PIs of these cases reported that without ATP/TDT funding, they would not have been able to make the links that furthered their research and the possibilities for student post-graduate employment or commercialization.

Case Study Profile: Code Division Multiple Access

OVERVIEW

CDMA is an example of a support technology whose path to commercialization is tied to the timing of the market entry of the primary technology. **Dr. Behnaam Aazhang and Dr. Joseph Cavallaro's** 1997 TDT grant deals with ways to improve the Code Division Multiple Access (CDMA), a multi-user wireless access protocol. The CDMA enhancement technology is part of the support system for 3G wireless technology. Commercialization is, in part, dependent of the market deployment of 3G systems. Nokia and Texas Instruments were the industrial partners. Two patents were issued and licensed to Nokia. The research helped secure a $700,000 NSF grant and approximately $1 million in additional funding from Nokia and Texas Instruments. The project has had a very positive impact on students, both in terms of summer and permanent employment within Texas and improved course content.

PROJECT BACKGROUND

The project dealt with ways to improve CDMA, a multi-user wireless access protocol. Dr. Behnaam Aazhang and Dr. Joseph Cavallaro, Rice University, Department of Electrical and Computer Engineering, received a 1997 TDT grant titled, "Development of Multi-user Transceivers for Wireless CDMA Communications." The grant covered the second phase of a successful project funded by a 1995 ATP grant titled, "Advanced Signal Processing for Multi-user Wireless Communications." In phase one, the principle investigators (PIs) and their research team developed signal processing algorithms and architectures for channel estimation and data detection for wireless multi-user communication systems. The TDT grant covered the second phase of the overall effort. The goal was to develop digital signal processor (DSP) based transmitters/receivers for the next generation of cellular mobile radio systems. Nokia and Texas Instruments (TI) were the industrial partners for both the ATP and TDT grants.

RESEARCH PROCESS

This project focused on the implementation aspect of next-generation CDMA wireless communication systems, specifically the two key elements of the base station receivers, channel estimation and multi-user detection. Figure 1 shows key blocks of Channel Estimation and Multi-user Detection studied in this project. During the course of the project, the PIs designed efficient algorithms and architectures to meet the real-time requirements of future wireless base-stations receivers.

Multi-user Channel Estimation and Detection, two of the most computer-intensive base band tasks in the receiver, were implemented on DSPs for performance evaluation. The multi-user detection algorithm was modified for a simple, pipelined structure. A General

Purpose Processor (GPP) or DSP based architecture with reconfigurable support suited for different wireless communication standards was proposed. Figure 2 demonstrates the project's improvements in channel estimation and Figure 3 the multistage detection enhancements. The improvements from the project's Differencing Multistage Detector are shown in Figure 4**.**

Figure 1 - Block Diagram of CDMA Base Station Physical Layer showing key blocks of Channel Estimation and Multi-user Detection studied in this project.

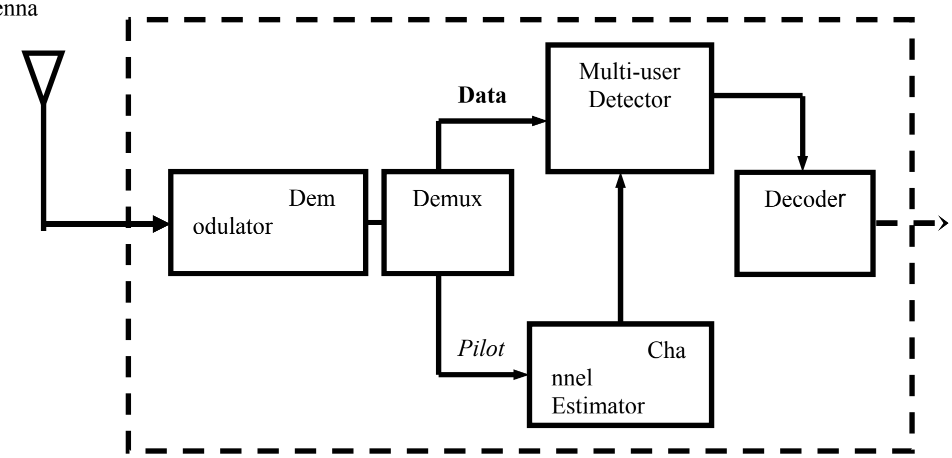
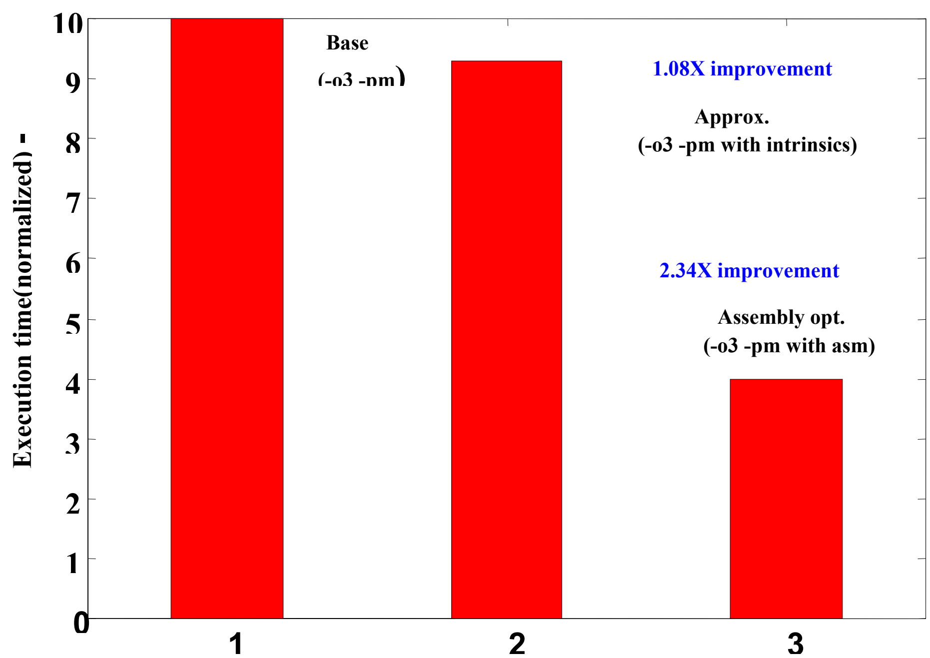
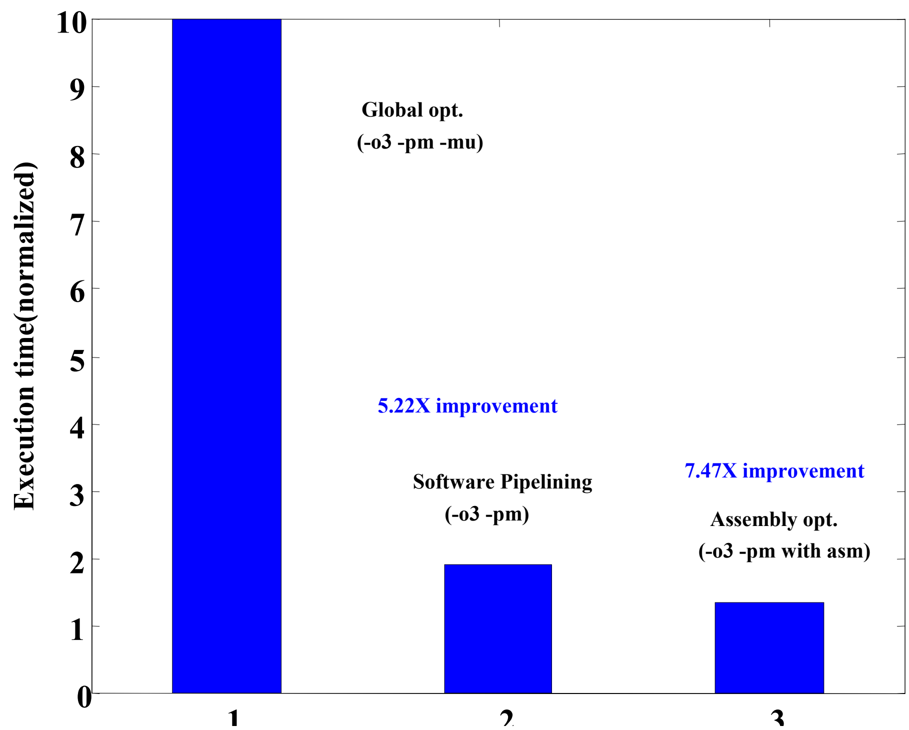


Figure 2 - Effect of optimizations for Channel Estimation on TI C6701 DSP



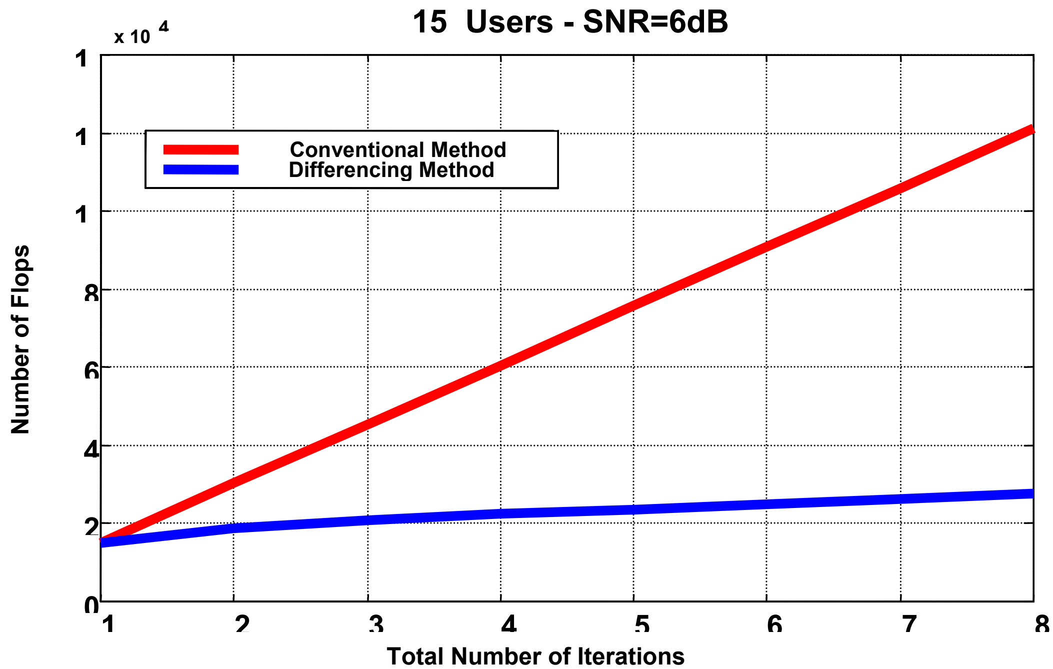
CDMA Base Station algorithm performance on TI 6701 floating-point processor. Improvements are due to software optimizations tailored to the numerical properties of the algorithm.

Figure 3 - Effect of optimizations for Multistage Detection on TI C6201 DSP



CDMA Base Station algorithm performance on TI C6201 fixed-point processor. The Multi-user Multistage Detection algorithm is further optimized through the creation of the Differencing Multistage Detector in the project shown in following figures.

Figure 4 - Differencing Multistage Detection Algorithm Performance



Performance improvement of Differencing Multistage Detection algorithm developed in this project. A speedup of 2X occurs at 3 iterations and a speedup of almost 4X occurs for 6 iterations in typical systems.

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TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Wireless communication systems and networks have ignited a booming industry with a tremendous market. The CDMA access protocol has recently emerged as a new standard in multi-user wireless systems for voice and data transmission. CDMA provides numerous advantages over traditional multiple access techniques for a wide range of multi-rate and multi-user applications, particularly for multi-path fading channels. The TDT technology offers improved performance, longer battery life, and increase user capacity for cellular systems. Because of the tremendous growth predicted for personal communication systems, user capacity is a major shortcoming in cellular radio industry and the proposed DSP-based systems will enable the wireless industry to meet these challenges.

Based on results from the 1995 ATP and the 1997 TDT grants, two patents have been issued to Rice University and were then licensed to Nokia. The CDMA enhancement technology is part of the support system for 3G wireless technology. Therefore, the commercialization of the technology is in part dependent of the market deployment of 3G systems.

LESSONS LEARNED

Nokia and TI were the industrial partners for the TDT grant. The research effort helped strengthen Nokia and TI's relationship with the PIs and other Rice programs. In part due to the results of the grant, the two companies have provided the PIs approximately $1 million in additional research funds between 1998 and 2002.

The research also helped Rice and the PIs secure a $700,000 NSF grant, titled "Seamless Multitier Wireless Networks for Multimedia Applications," for the period 1999-2002.

The TDT grant research has provided very positive impacts on students in several ways. As a direct result of the grant, more than ten students were hired as summer interns by Nokia and/or TI. In part because of their involvement in the grant research, at least two students are now employed in Texas by Nokia and TI. Dr. Aazhang teaches two graduate courses that have strong project component, and information from the research was integrated into several other courses.

Case Study Profile: Advanced Solar Cells for Space Applications

OVERVIEW

ATP helped create a pathway for significant change in a research program that is now recognized as a major player in space solar cell research. While the particular project did not generate significant tangible products, the project altered the mission of the Center. What had been a basic science group oriented to publications transformed itself into a center whose primary focus is to work with industry to solve specific problems. The transformation has led to a four-fold increase in the number of researchers and more beneficial economic impacts within the state of Texas.

BACKGROUND

The former Space Vacuum Epitaxy Center (SVEC) is a consortium of academic, government and private sector organizations founded to explore the possibility of using space to create commercially valuable materials superior to those produced today. Established in 1986 with a grant from NASA specifically to develop and commercialize new, thin film materials in the vacuum of space, the Center is located in 8,000 square feet of laboratory space in three buildings on the University of Houston campus.

Professor Alex Freundlich is the center's project leader for the Photovoltaics and Nanostructures Group, which focuses on the development of quantum-scale semiconductor heterostructures and exploratory materials for novel high efficiency solar cells. Such cells are useful in the exploration of outer space due to the rapid, world-wide proliferation of satellite-based communication systems. The Group investigates fundamental and applied materials problems to improve cell efficiency and decrease costs, and four patents have been issued to protect their work.

The ATP grant was awarded to Dr. Freundlich in 1993 with an in-kind matching financial commitment by International Stellar Technologies Inc. and Space Industries International Inc. in the amount of $470,000. The goal was to transfer the process and technology solar cells to the aerospace industry. The cells were compatible with existing manufacturing technologies and were expected to provide an end-of-life efficiency at least two times greater than any existing advanced solar cell without the usual shortcomings of standard space applications. Particular attention was to be dedicated to fulfilling space industry requirements. NASA was interested in the development of a prototype solar module and expressed the intention to work closely toward testing and qualification, anticipating a profound impact on electric power generation in space.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The project led to a small spin-off company, International Stellar Technologies Inc., which was eventually acquired by a British company. A patent also was issued as a result of the project, although there was no significant licensing. The greatest impacts, however, were in the orientations of the researchers and the Center's research agenda. Because of the ATP project, the research agenda changed from its prior basic research mission, and the SVEC engaged commercially as it increasingly focused its attention on various technologies in the satellite industry. Relationships in industry began to be cultivated, which resulted in additional research projects and greater career opportunities for graduating students. SVEC also created new alliances within the University of Houston, forming a new relationship with the University of Houston Business School. What started as technology evaluations evolved into collaborative teams of law students and students from various physical science disciplines looking at all aspects of commercialization.

As a result of this one ATP project, Dr. Freundlich's group changed its approach from concentrating on publications to seeing projects in the context of the development of a product.

Closer interaction with industry grew into streams of funding for the Center from NASA and the U.S. Air Force. While stronger ties with industry were not created instantaneously, ten years after the start of the ATP project, the SVEC was recognized as a major player in space solar cell research. Dr. Freundlich's group has grown from five to more than twenty scientists. SVEC, which later became the University of Houston's Texas Center for Superconductivity and Advanced Materials, now is part of a center that employs more than 200 workers. Center researchers have developed fifteen new technologies, published more than 450 scientific papers, and received more than $80 million in research funding.

Dr. Freundlich believes significant economic benefits to the State of Texas accrued both directly and indirectly as a result of the project. Tools were set in place at the Center that led to ongoing technology commercialization in the form of interaction of students from business, science and legal disciplines, and scientists acquired the ability to read and write patents. Perhaps most importantly, the Center now consists of professionals who consider themselves problem solvers, who strive for solutions needed by customers. Researchers are now creating new technologies capable of further commercial development. In 1993 Texas was virtually absent in the space solar cell industry. Today, the Center is regarded by many as the leader in its field.

LESSONS LEARNED

The project had significant unintended consequences which could not have been anticipated prior to the project. According to the PI, "Involvement with the ATP program has been an eye opener for the entire Center and for over a decade has continued to be a major factor in fostering an approach to our research that is interactive with industry."

Case Study Profile: System for Developing Near-Optimal Estimators and Classifiers

OVERVIEW

As a result of his 1997 ATP grant titled "Integrated System for Developing Near-Optimal Estimators and Classifiers," **Dr. Michael T. Manry** of the University of Texas at Arlington (UTA) started a company called Neural Decision Lab, LLC, of which he is president. Dr. Manry is a faculty member in the Electrical Engineering Department and also the director of the Image Processing and Neural Networks Lab (IPNNL) at UT Arlington. The technology he developed is also being used in five courses offered at UT Arlington. Additionally, the project allowed Dr. Manry to develop many lasting industrial connections, some of which are currently using software he developed.

PROJECT BACKGROUND

The primary purpose of the research project was to "develop, demonstrate, and transfer to industry unique technology for the automatic generation of near-optimal algorithms for parameter estimation of classification." The commercial potential of the proposal was widespread, with applications in endpoint detection in the semiconductor industry; flight load synthesis in the helicopter industry; power-load forecasting in the electric utility industry; pattern classification in the defense industry and many other such applications.

RESEARCH PROCESS

Research funded by a $95,040 ATP grant on the project began in 1997. The project allowed Dr. Manry to develop a new training method for the multilayer perceptron (MLP) neural network. He was also able to develop a method for combining several MLP networks into one improved network. The project and the resulting additional research facilitated the training of thirteen students (masters and doctoral students combined). At this time, three doctoral students and one masters student continue to work on the project with Dr. Manry. The students are now integrating software that was developed during the theoretical phase of the project.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The ATP project allowed Dr. Manry to develop industrial connections with the following companies: Raytheon in Garland, Texas; Bailey Network Management in Sugarland, Texas; Bell Helicopter Textron in Fort Worth Texas; Lockheed Martin and Halliburton Well Services. Of the industrial partners, Dr. Manry continues to work with Bell Helicopter Textron, which is currently testing a beta software related to the ATP project. Bell is comparing Dr. Manry's software to that developed by a U.K. company, and it is possible that they will eventually license the software from Dr. Manry. Additionally, Lockheed Martin in Grand Prairie is using software Dr. Manry developed in their automatic target identification program for a weapons system.

As a result of commercialization of the technology developed by the project, Dr. Manry was able to conduct further research for various government agencies. For industrial entities, Dr. Manry has used the technology for various research contracts, some gift supported research and also for consulting. Some of the recent projects that he has worked on include:

Power load forecasting system developed for Bailey Network Management
- Reservoir inflow prediction system developed for Bailey Network Management
- System for road location from aerial imagery for Hughes Training, Inc.
- System for endpoint detection in semiconductor processing for Verity Instruments
- Neural networks for flight load synthesis and flight condition recognition for Teledyne Controls and Bell Helicopter

In addition, Dr. Manry has also customized the commercial software, adding options such as new networks, new training algorithms and additional pre-processing options. He has also produced various software packages for forecasting and prognostics. Finally, he has undertaken source code development for digital signal processing, image processing, pattern recognition and neural networks.

Dr. Manry feels that UT Arlington has not made it easy for researchers to start a company in the past because of their retention of a fifty percent share of the gross revenues from intellectual property. He feels that the unfairly high percentage has delayed commercialization of IP, and allowed it to dwindle in value over time. Hopefully, the local technology incubator, Arlington Technology Incubator, which is a joint venture of the city of Arlington and UT Arlington, will be helpful to those who want to start a company. Currently, the ATI is awaiting critical UT Arlington signatures necessary to proceed.

LESSONS LEARNED

The project has enhanced the prestige of the IPNNL. A few of the organizations that the IPPNL has received funding from are the National Science Foundation (NSF); the National Aeronautics and Space Administration (NASA); E-Systems, Garland and Greenville divisions; Loral-Vought and Teledyne Controls and Electric Power Research Institute (EPRI). Although the ATP project was not directly responsible for Dr. Manry's receipt of the above-mentioned research funding, he stated that the ATP funding was crucial in terms of getting his research started. He said that the subsequent 1999 ATP grant that he received was directly attributable to the 1997 ATP project.

The economic impact for the state of Texas is evident in the number of students (more than thirteen) who have been trained working on the project and the related research agenda. Additionally, the neural networks technology developed by the project is being used in five Electrical Engineering courses at UT Arlington. The courses are offered at lectures at UT Arlington, in live television format and also in videotape format. Thus, there have been immeasurable educational impacts as a result of the technology.

Case Study Profile: New Insulator of Integrated Circuits

OVERVIEW

A collaborative effort between Texas Instruments and professors at the University of Texas at Dallas and the Texas Engineering Experiment Station NanoFAB Center in Arlington assisted and strengthened a Texas company with cutting-edge research while simultaneously addressing one of the semi-conductor industry's biggest dilemmas. Millions in additional research funds have been channeled to Texas-based research as a result of the 1999 ATP grant and commercial results are expected within the next six years.

PROJECT BACKGROUND AND RESEARCH PROCESS

Moore's Law states that the number of transistors per integrated circuit should double approximately every 12 to 18 months. As integrated circuit technology advances, silicon dioxide (SiO_2) dielectric films, the current industry standard, prevents the continuing down-scaling of electrical circuits due to electrical leakage. Working collaboratively through different institutions, **Dr. Robert Wallace,** professor of electrical engineering and physics at the University of Texas at Dallas and **Dr. Wiley Kirk,** professor of electrical engineering at the University of Texas at Arlington and director of Metroplex Research Consortium for Electronic Devices and Materials (MRCEDM), realized the need for alternatives for silicon dioxide dielectric films and their importance to the semiconductor manufacturing industry. In 1999, Drs. Wallace and Kirk were jointly awarded ATP grants to investigate novel high-permittivity gate dielectric materials for advanced microelectronics. The research focused on the thermal stability of two novel materials, hafnium (Hf) and zirconium (Zr) silicate dielectric films.

The results of the research demonstrate that Hf-silicate films exhibit better thermal stability than Zr-silicate films. Concurrently, Hf-silicate films are a better candidate for advanced transistor applications as integration into the integrated circuit fabrication process requires thermally stable films. Although not yet perfected for manufacturing, the research is in high demand by semiconductor manufacturers as the limits of SiO_2 dielectric films are being approached. As a result of the ATP grant, the project was awarded $2,798,000 through the U.S. Army ($1,823,000), DARPA ($700,000), and the Semiconductor Research Corporation ($275,000) to continue research, exemplifying the national interest for the project. Similarly, universities in MRCEDM provided an additional $1.35 million to modernize their research facilities, in part due to Texas Instrument's equipment donations and the funding of the ATP grant.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The research team has been working closely with Texas Instruments in Dallas to further develop the technology, established through the PI's collegial connections. Dr. Wallace and Co-PI Dr. Gnade are both former employees of TI, allowing them to direct research towards the needs of the Texas semiconductor industry. Wallace was a co-inventor of the technology. Including joint publications and in-kind characterization support, TI has also given $40,000 back to the university to support the collaboration. In 1999, Texas Instruments donated $6 million in research equipment to the Dallas/Ft. Worth Metroplex Research Consortium for Electronic Devices and Materials (MRCEDM). The researchers used some of this equipment during the ATP project, demonstrating the circular benefits of TI's dedication to collaborative academic research.

The new technology will be in high demand by semiconductor manufacturers like Intel, IBM, and Freescale and foreign technology companies in Japan, Taiwan, Korea and Europe. Since many of the research results obtained through the collaboration with Texas Instruments are competitive and proprietary, details on specific discoveries and patents are unavailable. However, TI is working towards commercialization and should begin integrating these new dielectric films into the manufacturing process within the next six years. Production will likely begin with small products like cellular phones, and eventually trickle down to the PC level and other everyday electronics.

LESSONS LEARNED

Texas-based research sponsored through the ATP grant strengthened Texas Instruments and increased the pool of highly trained specialists in the state. It provided valuable experience for student researchers, increasing their employability. One doctoral student now works for Texas Instruments in Dallas and one undergraduate student is now employed by Lockheed Martin in Fort Worth, both direct results of the ATP funding. Similarly, the grant provided experience and employment for post-doctoral research personnel, vital to continuing research momentum. In total, the grant supported fifteen researchers.

The new oxide insulator researched under the ATP grant could minimize or eliminate one of the biggest roadblocks in the semiconductor manufacturing industry, continuing down-scaling of integrated circuits. The collaboration resulted in modernization of university research facilities. As a side note, the PIs would like to see increased flexibility by the Higher Education Coordinating Board in budget management. According to the PIs, more flexibility in shifting funds across budget categories should be allowed because retaining researchers is difficult as salary monies are exhausted.

GROUP 5: SIGNIFICANT STUDENT IMPACT

Group 5 consists of case studies that demonstrate a disproportionately large impact on the students, both graduate and undergraduate, that worked on the projects. From gaining valuable research skills to making contacts in industry, students employed on ATP/TDT projects leave their labs with valuable work skills and are an immediate asset to the state's workforce. The following two case studies illustrate the effects which have occurred on hiring and training student researchers in the program.

Case Study Profile: Transgenic Technology Center

OVERVIEW

As a result of her 1989 Texas ATP project titled, "A Transgenic Technology Center," **Dr. Carole Mendelson** of the University of Texas Southwestern Medical Center at Dallas

(SWMC) was able to establish a Transgenic Technology Center at SWMC. Currently, Dr. Robert Hammer (who served as an advisor during the initial stages of the establishment of this facility) is the center director. The ATP project provided training for more than 72 students over the years, and was invaluable towards further research in the transgenic area.

PROJECT BACKGROUND AND RESEARCH PROCESS

At the time the researchers proposed the project, transgenic animals had become an essential part of biomedical research. The Transgenic Technology Center was initiated in 1990 with a $200,000 ATP grant to Drs. Carole Mendelson and Ray MacDonald. Through the creation of transgenic mice, researchers at the facility could address fundamental questions regarding mechanisms for developmental and tissue-specific regulation of gene expression; to establish immortalized and differentiated cell lines; and to analyze mechanisms involved in cell transformation and oncogenesis. They also proposed utilizing the Center as a means for training graduate students and fellows in this important technology. Approximately two years ago, the Dean of Southwestern Medical School agreed to make the Transgenic Technology Center (TTC) a bona fide core laboratory of SWMC. Thus, the school's subsidization allowed the Center to expand its resources, making transgenic technology more readily available to investigators throughout the campus.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The aim of the project was to set up a facility where transgenic mice could be "created." Thus, although commercialization of the lab setup was never intended, many researchers have benefited from the lab with great success in commercializing research.

The TTC is a campus-wide facility that has served numerous investigators in various departments throughout SWMC. It is estimated that the presence of the TTC has indirectly contributed to investigators receiving additional funds totaling $22.5 million.

At the facility there exists the capability to isolate cells from various tissues of transgenic animals to develop cell-culture models that retain properties that are unique to those tissues. Additionally, the animal models created can be used to over-express or inactivate certain genes. The transgenic mice the facility generates can be used to model human disease and also to determine how genes are regulated.

Transgenic technology is also employed in every major medical school in the country. As a result, the Center is invaluable to further student learning and research. Many researchers who use the facility do so with the intention of training as many students as possible. It is estimated that at least 72 students in total have been trained at the facility. Most of the students go on to work in various federal research

LESSONS LEARNED

The TTC has provided UT Southwestern investigators genetically manipulated animal models for research. MTAs have led to the discovery of the molecular mechanisms whereby physiologically and medically important genes are regulated, as well as to the development of mouse models of genetic diseases and cancer. In addition, through their discoveries, UT Southwestern investigators have been successful in applying for grants from the NIH, NSF, the American Heart Association, March of Dimes and small nonprofit organizations. The facility has grown significantly since its founding and has been now been made a subsidized Core Laboratory of UT Southwestern Medical Center. The TTC has been responsible for the creation of genetically manipulated mice for additional investigators on the campus, as well as to develop new technologies, including conditional and tissue-specific gene knockouts.

Image courtesy Dr. Robert Hammer TCC programs.

Dr. Mendelson felt receiving funds from the State of Texas to start the Center placed her in a unique position on the SWMC campus, and added that the ATP funding was very important to the success of the project. Although the project was different from other ATP projects in that commercialization of the research results was not one of its goals, it had an indirect positive impact on numerous other commercialization attempts.

The availability of services and the benefits to research helped to further enhance UT Southwestern's reputation as an outstanding institution for biomedical research, which has increased its ability to recruit and retain faculty members and medical students.

Case Study Profile: Deep UV Resists

OVERVIEW

The microlithography process is used in the manufacture of all semiconductor devices. The process depends on the use of photoresist materials. The resolution of the microlithography process depends on the exposure wavelength—the shorter the exposure wavelength, the higher the resolution of the process. The principal investigator had developed materials with sensitivity in the short wavelength, the "Deep UV" spectral region, but these systems required the use of "chemically amplified" resists that are extremely sensitive to airborne contaminants. Realization of the higher resolution the materials provide required special handling and air purification. The chemically amplified resists could not readily be used for manufacturing photomasks because the infrastructure required for protection from airborne contamination did not exist and the mask blanks had to be stored for long periods of time.

In the 1993 TDT project, **Professor Grant Willson** worked in collaboration with Dr. Dammel of AZ Photoresists Products, a business unit of Hoechst-Celanese, to develop new deep UV resist technology which could impact semiconductor and mask manufacturing efficiencies. The relationship ended when Hoechst-Celanese was acquired by Clairant Ltd. Consequently, chemically amplified technology, although still not performing as expected, was adopted by the semiconductor manufacturing industry and is being incorporated into mask manufacturing. Work on the new deep UV resist technology has continued and is being tested by photomask manufacturing companies in Round Rock, Texas. If the experiments are successful, products could be marketed in two years.

PROJECT BACKGROUND

In a previous ATP project Dr. Grant Willson and his team designed a molecule that performed in the deep UV spectral region in the same way as the chemically amplified resists currently used in semiconductor manufacturing, but without sensitivity to airborne contaminants. The other resists being used were designed using chemical amplification and react to the same deep UV range of the light spectrum; however, these deep UV resists are extremely sensitive to small amounts (10 parts per billion) of basic contaminants in the air. While improvements in the process are continuing, the process still requires special air handling, purification and process controls that adversely affect cost.

RESEARCH PROCESS

The PI and his team did much of the initial discovery research. After successfully developing a new photosensitive compound, they worked closely with Hoechst-Celanese manufacturing personnel to develop methods for viable commercial production of the new material. Worked proceeded as planned with the photosensitive material, however, development of the new penolic polymer proved much more difficult. The initial group of polymer candidates was carefully explored, however none of the materials provided the necessary performance for use in formulating deep UV resists. At that point in the research, Hoechst-Celanese in Corpus Christi was sold, the personnel who were working with the UT researchers were dismissed, and new relationships had to be established with Clariant personnel in New Jersey. While the work led to the development of another new class of photosensitive materials, no new and promising class of polymers was discovered; the formulated resist could not be created.

To continue investigating the compound, UT Austin signed a new $800,000 research contract with an Oregon company, Etec Systems, Inc. The contract produced another much-improved photosensitive compound and generated a great deal of valuable data, but it did not lead to the elusive new polymer. Ultimately, the PI engaged in a series of research contracts sponsored by SEMATECH that led first to resists that were sensitive to 193nm exposure and, most recently, to materials that are sensitive at 157nm. In the course of the most recent undertaking, the elusive resin that was required for the original Deep-UV application was discovered serendipitously. The PI is currently working to optimize formulations based on these materials and has an agreement with Mask Companies in Round Rock, Texas to test the materials.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The purchase and closing of the industrial sponsor's plant in Corpus Christi nearly ended any prospect of commercializing the technology as originally envisioned. The disruption caused the less robust, chemically amplified technology to be adopted. While the alternate technology is more expensive and cumbersome to use, the companies are committed to it and are now progressing toward implementation of the 193nm resists like those developed in the PI's laboratories.

Semiconductor Research Corporation, Sematech, ISI Inc, TEL, Japan Synthetic Rubber Co., DOW Corning, DuPont Photomask and Etec Systems, Inc. recognized the potential of the technology being developed by Dr. Willson's team and contributed funds and technicians to help complete the research project. The significance of the technology was the subject of many articles. Kyle Patterson, one of the graduate students working on the project, had the honor of making the public announcement of the advancement and was interviewed on CNN. Subsequently, he received several job offers and now works for Freescale Semiconductor, with responsibility for the critical gate level of their most advanced device.

During the course of the project, another of the student team members was hired to work on the project by AZ-Photoresist, a Hoeschst-Celanese Company, while another was hired to work in Hoeschst-Celanese's Corpus Christi plant on resin composition. Five of the graduate students who worked on the project went to work in the same field after graduation. Two are working at Texas Instruments in Dallas and are responsible for the critical levels of their most advanced devices. Another works at Samsung in Austin, another at Photronics in Round Rock, Texas and another at DuPont Photomasks, also in Round Rock.

LESSONS LEARNED

The technology being created in the project was able to survive a potentially fatal conclusion with the loss of their primary industrial sponsor because of its foundation on the results of a previous grant and the PI's insistence on the interaction of the graduate students with industry and the media. The students who worked on the project, now employees of Texas semiconductor manufacturing companies, are leading teams to complete commercialization of the product. Not only did they help create a new technology, they learned how to plan and conduct research, how to present their work in written and oral fashion, how to collaborate with industry and how to persevere when business does not go as expected.

While the technology may someday allow semiconductor manufacturers to create even smaller structures, it too will ultimately be replaced by a newer process. The students who worked on it will continue to be research leaders and managers in the semiconductor and photomask industry and the Texas economy will continue to benefit from their contributions.

The commercial significance of the technological advancement, the high level of interaction with industrial partners and the grant money received to complete the research has been a factor in UT's Department of Chemical Engineering's recruitment of some of the best graduate students in the country, some of whom might have otherwise enrolled at Cornell, MIT, or another "competing" university.

GROUP 6: LICENSING REVENUE

ATP/TDT projects have generated revenue for their host institutions by licensing technologies created from the research. Licensing arrangements vary from institution to institution and can take a variety of forms. Group 6 consists of cases that illustrate the variety of arrangements in use by award winners, and some of the cases, too, provide examples of problems in certain licensing regimes.

Case Study Profile: Solid Freeform Fabrication

OVERVIEW

The technology to depict three dimensional objects with computer aided design (CAD) software had been available for several years. The goal of the ATP project was to combine computer drawing and a computer-controlled laser to actually create 3D objects, otherwise known as Solid Freeform Fabrication (SFF). To accomplish the goal, a multi-disciplinary team (system design and modeling, information systems, materials science and engineering) was assembled. The team focused on the properties of the materials used which needed to be strong enough to be fashioned by the laser. The researchers also needed to improve a previously developed interface to control a laser with computer-electro-mechanical controllers by refining it so that the laser beam could be precisely placed on a surface with high speed and accuracy. The laser beam calibration also needed improvement.

PROJECT BACKGROUND

Advances in electro-mechanical technologies and power delivery had provided a degree of controllability such that a laser could be "guided" through a computer interface. Researchers in materials processing technology were also beginning to understand how different material surfaces reacted to a laser beam, what the thermal properties of the materials were and the structural quality of the material in its solid form. An Industrial Associates program comprised of eight major manufacturing companies was formed to provide financial support and expertise to the development of Solid Freeform Fabrication.

RESEARCH PROCESS

It was necessary to solve two fundamental problems before SFF could occur. First, a computer format that could represent any three-dimensional shape needed to be developed. Then the researchers needed to create a manufacturing process to fashion solid objects from the newly developed computer format.

The format they created resulted from subdividing a cube into N^3 smaller cubes, named voxels, short for volume elements. Each voxel could have one of two values, 1 for a solid or 0 for an empty state. The 3D object would be represented by all of the voxels with a 1 state; voxels with an empty or 0 state were removed.

The team manufactured the 3D object represented by the computer format by using a layered approach. Each layer of the object was one voxel thick, and by processing the layers, one on top of the previous, a three dimensional object could be fabricated.

By the end of the project, the team had developed technologies to measure manufactured parts quantitatively and qualitatively. While significant, the parts required minimal accuracy and were of minimal structural integrity. The knowledge stemming from the research was applied to the design of the next generation of experimental machines and test beds that will be used to further develop SFF.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Research support, technology transfer and industrial involvement were all promoted through the formation of the Industrial Associates Program by the PI, **Dr. Joseph Beaman, Jr.,** chaired professor of mechanical engineering, at UT Austin. The organization members were Ford Motor, General Motors, Pratt and Whitney, Gillette, BFGoodrich, Texas Instruments, 3M and DTM Corporation. At the end of the project, the group met to provide expertise to the ongoing development and technology transfer of the SFF process.

In 1987 an Austin entrepreneur, Paul McClure, approached the University of Texas at Austin's Center for Technology Development and Transfer (CTDT) in his search for a new technology to serve as the basis for a new company. He felt that SFF was a promising technology and, after securing world-wide licensing rights to it, formed Nova Automation. Nova was the first company to commercialize a technology from CTDT. DTM developed a 'beta' program of five partners (General Motors, Kodak, Plynetics, United Technologies and Sandia National Laboratories), who provided the project with a beta sintering prototype. The program participants provided feedback and input to the ongoing development of a commercially viable SFF hardware. The company, which had since changed its name to DTM Corporation, unveiled the first SFF machine at the Autofact Trade Show in October 1989. Their first product, the "SinterStation 2000," that implemented the Selective Laser Sintering (SLS) process, was available in late 1993. DTM, then valued at $45 million, was bought by 3D Systems of Valencia, California in the third quarter of 2001. 3D Systems reported $121 million in revenues that year.

Since its introduction in 1989, almost all of the Fortune 500 companies have purchased and are using at least one SFF machine. A variety of industries worldwide use the machines in manufacturing a broad range of components for their products. For example, Baker Hughes uses them to manufacture drill bit housings, Siemens manufacturers hearing aid shells with them, and Boeing has fifteen of the machines and is planning to spin off a division that will use them in the manufacture of aircraft parts. Formula 1 race teams also use SFF technology to design and fabricate unique parts for their cars.

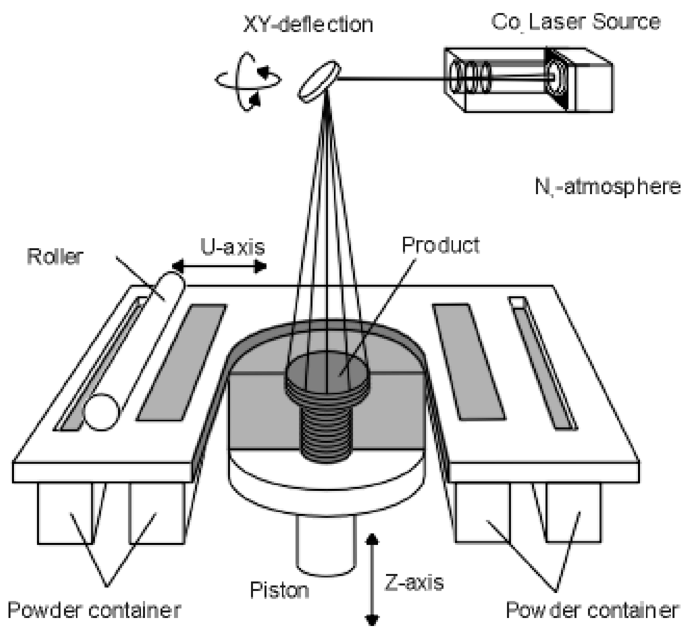
UT Austin has received approximately $5.2 million in licensing royalties from its initial license to DTM. The license was transferred to 3D Systems when the company purchased DTM in 2001.

LESSONS LEARNED

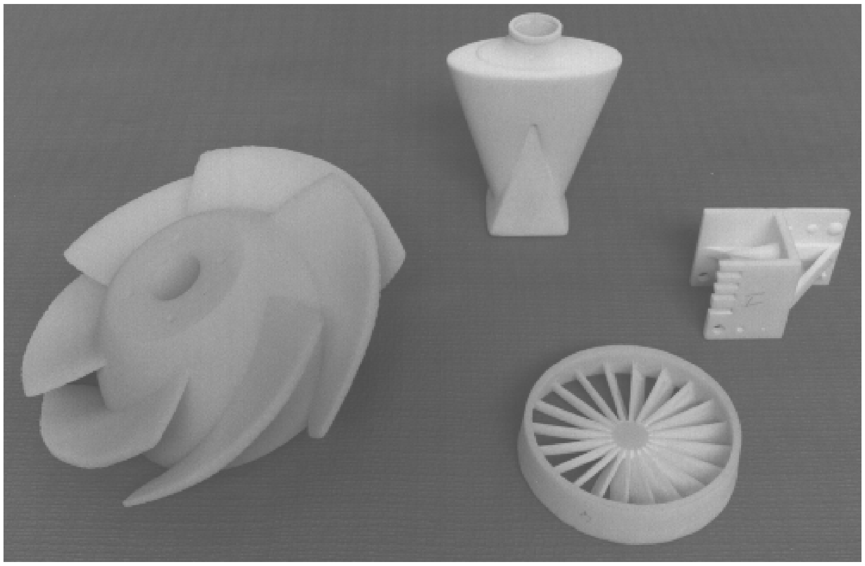
The early formation of an advisory group of key industry participants not only supported the research financially but also provided practical expertise and guidance. The entrepreneur's interest, the accessibility of information in the UT Center for Technology Development and Transfer, and the SFF technology itself, were instrumental in the formation of the new company. The conception of Nova Automation, with the goal of commercializing the technology, provided exposure and funding that may not have been directly available to the university. At least three of the students who worked on the project are working with the technology, one at an Austin company that uses a similar spin-off technology, and two who formed their own service bureaus in central Texas that provide consulting services to the SFF manufacturing industry.

Finally, the project exemplifies what may occur from multi-disciplinary collaboration. The involvement of several disciplines led to the development of a highly successful commercial product, which would not have been possible without collaboration across different research fields.

DTM Sinterstation 2000



Working Principal of the DTM Sinterstation 2000



Examples of SLS manufactured products (polyamide): an impeller, a perfume bottle, a fan and a test piece for benchmarking SLS product quality

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Case Study Profile: Marketable Flow Chamber for Multielectrode Recording, Optical Monitoring, and Laser Cell Surgery

OVERVIEW

As a result of a 1991 Advanced Technology Program (ATP) project titled "A Marketable Flow Chamber for Multielectrode Recording, Optical Monitoring, and Laser Cell Surgery," **Dr. Guenter Gross** from the University of North Texas (UNT) received two consecutive contracts from the Defense Advanced Research Projects Agency (DARPA) to develop "Neuronal Network Biosensors" in collaboration with the Naval Research Lab (NRL), Washington, D.C. International collaborations with the University of Rostock and the Technical University of Munich (both in Germany) and with the Los Alamos National Laboratory were triggered primarily by the support, and a company called Applied Neuronal Network Dynamics (ANND) was formed in January 2002 to assume responsibility for the fabrication of microelectrode arrays, chamber construction, and network shipping to customers. Dr. Gross is currently the Director of the Center for Network Neuroscience (CNNS) at UNT.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Gross' goal in developing a closed flow chamber was to enhance his earlier research. A long-term goal for him was to develop a turnkey system that could be used by industry and universities for investigations of nerve cell network dynamics and for application in the fields of toxicology, pharmacology, drug development, and tissue-based biosensors.

Because of substantial preliminary data, the basic design for a closed flow chamber was accomplished relatively quickly. Of great significance was the focus on simplicity, durability, sterilizability, and rapid assembly under sterile conditions. The prototypes Dr. Gross developed accelerated research and also led to a variety of unanticipated new ideas and implementations. Currently, the new chambers are being sold (non-profit) by the CNNS to numerous laboratories, and investigations in related areas began in rapid succession. The increased research output and constant feedback to Plexon Inc. (an industrial partner located in Dallas, Texas), allowed the development of improved multichannel data acquisition and processing systems that are sold world-wide. Plexon is now the premier supplier of multichannel hardware and software.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The project had a strong influence on the neuronal network research domain, helping attract students and external funding. Also, many international researchers were trained in the new methodology at the CNNS. The tangible products continue to be marketed by CNNS (www.cnns.org). Since 1991, CNNS has published 51 papers and Dr. Gross has been invited to 64 national and international seminars. An international conference (Simea2003) was sponsored by CNNS and held in Denton, Texas in March 2003.

Spontaneously active networks are dynamic systems that react to chemical compounds in a highly similar manner as the intact nervous system of a mammal. Consequently, they represent effective screening platforms for the rapid, quantitative evaluation of the toxicity of new compounds or mixtures of known compounds. As a prescreening step, such platforms should provide extensive information before animal experiments commence, thus saving time, money, and animals. Although the investigation of network dynamics is at the frontier of brain research, the greatest efforts have been made in finding applications to industrially pertinent areas such as toxicology, pharmacology, drug development, and biosensors.

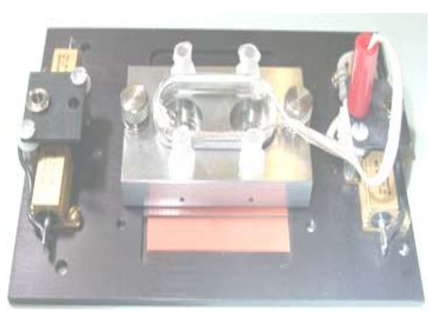
Applied Neuronal Network Dynamics (ANND) is presently out of funds and almost inactive. It is anticipated that future expansion to multinetwork chambers will trigger interest in the areas of toxicology, neuropharmacology, and drug development, and may lead to a revival of ANND. Dr. Gross feels that the dormancy of ANND is partially attributable to general lack of enthusiastic support by university officials. According to Dr. Gross, at many institutions, there is a lack of understanding of innovations and their legal ramifications, which generates fear of "something going wrong." Hence some universities tend to stifle the growth of new technologies as they are overcautious, legally uncertain, and sluggish in their response. Under such conditions, the vital supportive atmosphere becomes instead a "policing" atmosphere, according to Dr. Gross.

LESSONS LEARNED

Although ANND failed to achieve full operational status, CNNS is still marketing chambers and microelectrode array plates (www.cnns.org) to research laboratories. CNNS is also still shipping networks to the NRL and to the Naval Health Research Center, and it is also testing anti-prion peptides for Adlyfe (Arlington,Virginia). Hence, the potential for future technology transfer is still alive. A direct transfer of know-how to Plexon in terms of pharmacologically-pertinent software and general new approaches to network data analysis was successful and is expected to help Plexon compete with Multichannel Systems Inc. in Germany.

In Dr. Gross' opinion, one of the factors that was instrumental to the 'mothballing' of ANND was that all experimental work still had to be performed in CNNS labs with 'soft money' technical support and relatively primitive facilities (especially for photoetching). ANND was required (by UNT) to rent equipment time and technical support time from CNNS, which further increased the complexity of the operating environment at ANND.

The project had substantial impact on subsequent grant procurement, attraction of new graduate students, retention of key faculty members in Texas, and placement of students in desirable positions. One Ph.D. student became a post-doctoral student in the laboratory of Nobel laureate Gerald Edelman (La Jolla). Additionally, as a result of the ATP project, Dr. Gross received two contracts from the Defense Department (DARPA), each funding approximately $750,000 of research. He felt that the $1.5 million received would not have been forthcoming had it not been for ATP funding.



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Dr. Gross also suggested that since ATP funds are State funds, it would be prudent to provide State guidance in order to use these funds as efficiently as possible and assist new companies during their critical start-up phase. If done properly and if intellectual property is not taken away from the university, he feels that such expert guidance would be welcome by most universities and also their administrators.

Two chambers designed in 1991. The single network chamber (left) was used extensively starting in August of 1991 and accelerated research. The dual network chamber (above) was designed in 1992, but was not used extensively until 1998 (DARPA projects).

Case Study Profile: Pasteurella haemolytica

OVERVIEW

Dr. Highlander's project offers an example of use of information gained from a TDT project to redirect research efforts towards a more likely commercialization path. The technology deals with genetic based vaccines for shipping fever pneumonia in cattle. The goal of Baylor College of Medicine's **Dr. Sarah Highlander's** 1997 TDT grant was to prepare a vaccine for the USDA Veterinary Biologics approval process. Boehringer-Ingelheim Vetmedica was the industrial partner. Results of the TDT project were inconclusive and Boehringer-Ingelheim decided not to continue the partnership. Following the TDT research, a more conventional subcutaneous injection approach was evaluated with very positive results. A patent, titled "Pasteurella haemolytica vaccine," for Baylor's mutant vaccine strain was issued in 2001. In 2002, with seed funding support from Baylor's BCM Technologies, Inc., Dr. Highlander and others formed Prokaryon Technologies, Inc. Prokaryon licensed the technology in March of 2003. Prokaryon is currently seeking appropriate funding to enable them to initiate the USDA approval process.

PROJECT BACKGROUND

Dr. Sarah Highlander, Baylor College of Medicine, Department of Molecular Virology and Microbiology, received a 1997 TDT grant titled, "Pasteurella haemolytica Vaccine Strains. The 1997 TDT grant followed a 1995 ATP grant titled, "Pasteurella haemolytica vaccine strains that produce attenuated leukotoxin." The primary goal of the TDT project was to field test a recombinant strain of bacteria for efficacy as a live vaccine to prevent shipping fever pneumonia in cattle. The project was to include 1) safety testing of the strain, 2) vaccine-challenge studies, and 3) vaccine strain improvement. Boehringer-Ingelheim Vetmedica was the industrial partner for the TDT grant.

RESEARCH PROCESS

Baylor's 1995 ATP grant helped fund Dr. Highlander's and her colleagues' efforts to create and characterize new strains of Pasteurella haemolytica bacteria for possible use as a shipping fever vaccine. Two strains were developed. The first took approximately 12 months to complete and the second involved a 24 month research effort. The second strain lacks an antibiotic resistance marker so is in compliance with USDA guidelines for live bacterial vaccines. In March of 1999, the virulence of the second recombinant strain was tested in a calf-challenge experiment. The calves were injected transthoracically with wild type or recombinant bacteria and the animals' responses were followed. Four days after the challenge surviving animals were evaluated. The results of the analysis indicated that the recombinant strain still retained significant virulence and suggested that the strain might not prove safe as a live vaccine. As a result, vaccine-challenge experiments were not performed. The research team, however, decided to continue attempts to create a more severely attenuated mutant strain and/or to examine different application approaches for the current strain.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

The global veterinary vaccine market for livestock exceeded $1.1 billion in 2000. The most economically devastating bacterial disease in the U.S. cattle industry is shipping fever (pneumonia in cattle). The technology associated with the TDT grant, and a preceding ATP grant, deals with genetic based vaccines for shipping fever.

Boehringer Ingelheim Vetmedica was the industrial partner for the TDT grant. Experimental animals and facilities for testing were provided that are not available at Baylor College of Medicine. Boehringer assisted the Baylor research team with appropriate planning for animal testing. As summarized in the Research Process section, the virulence of Baylor's second vaccine strain was tested and the results indicated that the recombinant strain might not prove safe as a live vaccine. At the conclusion of the virulence test Boehringer Ingelheim elected not to pursue further development and testing of a Baylor strain.

The project is an example of using information gained from a TDT project to redirect research efforts towards a more likely commercialization path. Following the TDT grant project, Dr. Highlander and her colleagues decided to continue attempts to create an improved bacteria strain and/or to examine different application approaches. A more conventional subcutaneous injection approach was evaluated for use with Baylor's second recombinant strain. Research results were very encouraging.

A strong patent with broad claims for Baylor's second strain, called "Pasteurella haemolytica vaccine," was issued in 2001. Based on results of the TDT project and the follow-up research, Dr. Highlander and others decided to commercialize the Baylor recombinant strain utilizing the subcutaneous injection approach. Prokaryon Technologies Inc. (http://www.prokaryon.com/) was founded in August 2002. Baylor College of Medicine licensed the technology to Prokaryon in March, 2003.

BCM Technologies, Inc. (BCMT), the venture development subsidiary of Baylor College of Medicine, provided approximately $500 thousand in seed funding. BCMT (http://public2.bcm.tmc.edu/bcmt/default.cfm) was formed in 1983 to promote the commercialization of Baylor College of Medicine faculty inventions through the formation of new companies. BCMT is an integral part of the process of evaluating the potential of new technologies as the basis for new business enterprises.

Prokaryon Technologies, Inc. was created to develop and market products to prevent and control infectious diseases in animals. The company will be using proprietary genomics-derived platform technologies, licensed from Baylor College of Medicine.

Prokaryon's first product, SureVax™ Mh vaccine, will utilize Baylor's bacterial strain. In October and November of 2003, Prokaryon conducted a very successful test of the vaccine strain. SureVaxTM Mh is predicted to provide greater than 70% protection against shipping fever compared to currently marketed vaccines. At the present time, the vaccine is forecasted to enter the Final Efficacy phase of vaccine development, and could be approved for use by USDA Veterinary Biologics within two years, based on current approval times.

Prokaryon is currently seeking appropriate resources and/or an industry partner in order to begin the USDA approval process for SureVax™. To date there have been discussions with several investment groups and potential corporate partners.

LESSONS LEARNED

With support of the ATP and TDT grants, Baylor College of Medicine was able to receive a strong patent for the Pasteurella haemolytica vaccine. Combined with follow-up research by Dr. Highlander, the patent led to the formation of Prokaryon Technologies Inc., utilizing seed funds from BCMT.

Dr. Michael Dilling of the Baylor Licensing Group indicated that commercialization prospects were greatly enhanced when Baylor received the patent for Dr. Highlander's vaccine with broad claims.

The case reinforces the concept that champions are vital in the complex world of commercializing new technology products. Clearly, Dr. Highlander has served in the role of the technology champion. Without her continued hard work to build on the results of the TDT research, commercialization efforts would have stopped several years ago. BCMT played a vital role in the formation of Prokaryon. The business champion for the formation of Prokaryon was Dr. Edward McGruder. Dr. McGruder had been the head of the Acquisitions Department of Elli Lilly. When looking for new medical related opportunities he became aware of Dr. Highlander's patent and made contact with the Baylor Licensing Group. Networking into Baylor College of Medicine by Dr. McGruder was particular important because Dr. Highlander's technology was outside the mainstream research areas of the university.

Dr. Highlander and Dr. McGruder both stress that in the commercialization of products for the animal vaccine market, it is imperative to have a working group that includes those with direct business experience in the market and a strong animal medicine technology background. Potential initial customer participation early in the process also provided a very positive influence.

The case supports the idea that technology commercialization can take many years to come to fruition. Medical technologies have long gestation periods, both through the process leading to federal trails and during the trials themselves. Everything takes more time than anticipated for medical products, even those for animals.

Case Study Profile: Conversion of Waste Biomass to Mixed Alcohol Fuels

OVERVIEW

The research has led to ten issued U.S. patents with claims directed at process steps that convert biomass (e.g., municipal solid waste and sewage sludge) into alcohol fuels. The integration of the process steps, through the assistance of an ATP grant, helped lay the technical foundation for Terrabon, a new Texas company formed to commercialize the technologies. The technology has evolved to the pilot plant stage of development. A $5 million demonstration plant is being planned. Since 1995, over $2 million has been invested to commercialize the technology.

For its positive environmental and economic impacts, the EPA and the American Chemical Society have recognized the technology with the 1996 Presidential Green Chemistry Challenge Award, given by the President of the United States.

PROJECT BACKGROUND

Since 1978, **Dr. Mark Holtzapple** has worked on processes for converting biomass into alcohol fuels. Since 1986 his research has been performed at the Texas Engineering Experiment Station at Texas A&M University in the Department of Chemical Engineering. Dr. Holtzapple's technology led to the formation of a Texas-based company, Terrabon, for the purpose of commercializing the processes. The company has funded all patent applications, contributed $100,000 per year to support further research, and invested additional funds to build a pilot plant

RESEARCH PROCESS

Each of the process steps had been shown independently to work in a laboratory setting. The goal of the project was to use the output of one process step as the input to the next process step, showing that the steps can be integrated into a coherent whole. The logical sequence was to begin work on the first process step (pretreatment), send the pretreated material to the next process step (fermentation), and then move to the next step (concentration), and finally the last two stages (thermal conversion and hydrogenation). While work is done in the initial two stages of the process the equipment needed for the last two stages, thermal conversion and hydrogenation, would be constructed.

Measurements were taken at each stage so the process could be integrated in an optimal manner. The research was successful—all the process steps were integrated and worked well as a unified whole.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Mr. David Carrabba, an A&M alumnus from a family of entrepreneurs, approached the Texas A&M Licensing and Technology Office looking for a technology that had promising commercial potential. He was excited about the biomass conversion process, acquired the licensing rights to the technology and formed Terrabon. The start-up company provided resources to continue the research, funded the patent applications and to date invested over $2 million to bring the technology to market. Currently, the pilot scale of development is nearing completion, which will process about 200 pounds per day of feedstock and about 15 gallons per day of ethanol fuel. The pilot should be operational in fall 2004. The results from the pilot plant will be used to design a demonstration plant that will process about 50 tons per day of feedstock and produce about 8000 gallons per day of ethanol fuel.

Research funding has come from many sources. The U.S. Department of Agriculture (USDA) sponsored a study to learn why the lime pretreatment is so effective. The Gulf Coast Hazardous Substances Research Center (GCHSRC) funded the study on using industrial biosludge and recycled paper fines in the fermentation process. The Texas A&M Energy Resources Program sponsored work on the hydrogenation process and had previously funded research on specific phases of the thermal conversion process. The chemical company Celanese expressed great interest in the processes and provided additional research funding.

The university supported the technology and the Technology Licensing Office worked closely with Terrabon on the patent applications and licensing of the integrated processes. Terrabon is actively working to raise the $5 million needed to build the demonstration plant. One million dollars has been committed and another $1 million from a multi-national petro-chemical company is promised. With the National Renewable Energy Laboratory (NREL) focused on corn-derived ethanol fuels, it appears that the rest of the funding will have to come from private industry sources.

To date, no licensing revenues have been generated because the process is not yet fully commercialized. When it reaches the market, it has the potential to generate literally millions of dollars in annual royalties.

A spin-off technology has evolved that uses lime to solubilize proteins to make high-quality animal feeds. In addition, the process destroys prions, which will prevent Mad Cow disease from spreading through animal feed. The spin off has all of the earmarks of a highly successful project: success attracting a variety of funds, exciting spin-off technology, significant student involvement, and continuing success of a new Texas startup company.

LESSONS LEARNED

Familiarity with the university, the inherited entrepreneurial spirit and the resources to start a new company all played invaluable roles in the formation of Terrabon. Without the startup licensing the technology, it might have been relegated to scientific journal articles, a research laboratory at A&M and a binder in the Licensing and Technology Office.

The ten awarded and five pending patents, the success of Terrabon in building the pilot plant, and the interest in funding a demonstration plant all point toward the success of the project. Of the 50 graduate students who worked on the project over the course of 13 years, approximately half still work and live in Texas.

The key to success for the project was to use a base of solid technologies on which to build. There was a thorough understanding of what was learned in the previous research and the PI had a realistic view of the problems that would have to be addressed to serialize the five distinct process steps into an integrated process. A well-developed plan was used to achieve the goals set forth in the proposal. The creation of the startup company – the main purpose of which was to scale up the process to a commercially viable scale – helped keep the academic research focused on the technology allowing business issues to be addressed by the company.

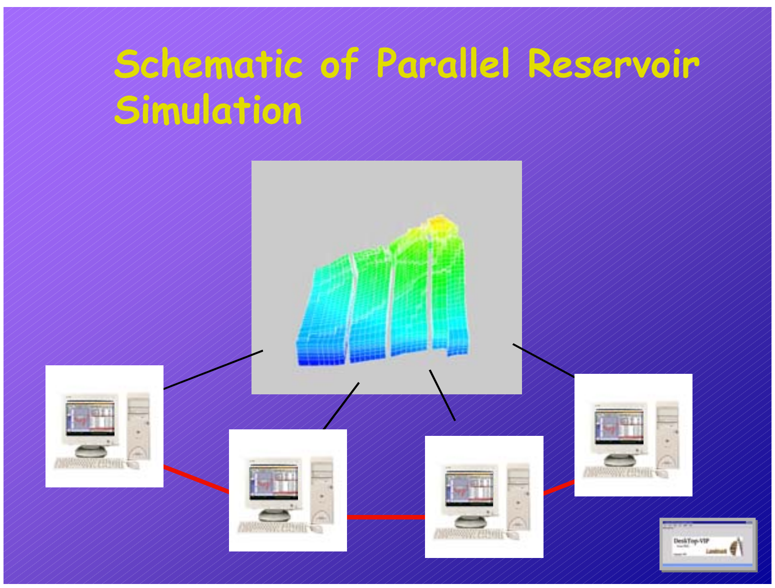
Case Study Profile: Commercialization of Parallel Reservoir Simulation

OVERVIEW

The Parallel Reservoir Simulation software package generated approximately 40 licenses in the oil and gas industry and earned more than $10 million in royalties. A Texas company whose parent was acquired by Halliburton owns the intellectual property rights. By making it possible to run simultaneously multiple large-scale model simulations of petroleum recovery in partially depleted reservoirs, the technology significantly reduces business decision risk in the oil and gas industry

PROJECT BACKGROUND

Much of project PI **Dr. John Killough's** previous research, sponsored by two consecutive ATP grants, investigated the feasibility of parallel petroleum reservoir simulations. The research resulted in more than $500,000 in funding from both governmental and industrial sources for a leveraging factor higher than two. Problems of scale-up and several key issues remained unexplored in the model's implementation in a commercial environment. The project sought to emphasize the investigation of large realistic models with complex geology.



The proposal focused on the commercialization of software tools that could be utilized in the analysis of petroleum reservoirs through the cooperative efforts of Western Atlas Software, Landmark Graphics Corp, IBM, Oryx Energy Company, the University of Houston Department of Chemical Engineering, and Prairie View A&M University. The ultimate research goal was a model that would allow simulations that would significantly reduce numerical errors. More efficient analytical methods for improved oil recovery help to better assess and reduce risk, enhancing economics in the industry. The researchers applied algorithms to IBM's Risc Station 6000 technology. The research led to the development of a commercial-quality parallel linear solver. Professor Kame1 Fotouh of Prairie View A&M, a simulation expert with twenty-eight years in the chemical and petroleum industries, acted as co-PI.

RESEARCH PROCESS

The project's goal was to develop a general-purpose, commercial reservoir simulator to make reliable predictions of oil recovery. The researchers realized the goal by devising reliable models for the prediction of improved oil recovery processes that were significantly more accurate and efficient than what the market offered. The code was released as a prototype version to the industrial participants in the project and the initial commercial release of the simulator followed the next year.

Over the term of the grant substantial additional funding received included NSF and DOE grants totaling in excess of $1.2 million and another of nearly $1 million from Los Alamos, Landmark Graphics, Oryx Energy, and IBM. After they graduated, students who worked on the project went on to desirable positions with Idaho National Laboratory, Purdue University, Frito Lay, Eli Lilly, Brown and Root, Honeywell and Technion University in Israel. Project benefits to Prairie View A&M University included the participation of a large number of minority engineering students and the establishment of a computational facility that led to the attraction of more well-qualified students. The students gained valuable academic experience, learning techniques that were professionally implemented on real reservoir simulation studies.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

By most measures the project was an outstanding success. A relatively young Texas company, Landmark Graphics, continues to hold the IP rights that arose from the research and continues to benefit from a large royalty stream. Landmark currently employs 40 workers in Houston. The research culminated in the development of a product that ranks second against a competitor's product.

Western Atlas provided software on which the original contract was performed. The PI was offered a management position with equity to collaborate in the commercialization of the technology, a goal articulated in the ATP grant proposal. All parties to the agreement benefited directly except the University of Houston, which recovered no royalties because IP rights were contractually precluded in the research arrangement.

The direct benefit to the State of Texas included continuing to be a leading oil producer and center of petroleum technology globally where significant improvements in tools for the development of petroleum reservoirs are first introduced. During the life of the project Landmark acquired an interest in Western Atlas Software. Landmark acquired Western Atlas entirely in 1996, and later that year, Halliburton acquired Landmark.

Three graduate students (University of Houston) and four undergraduate students (Prairie View) were involved in the research project. Because of the requirement of commercial quality, a post doctoral associate at each university was involved in the project. Most students went on with jobs in the oil industry.

Case Study Profile: PLx Pharma Inc.

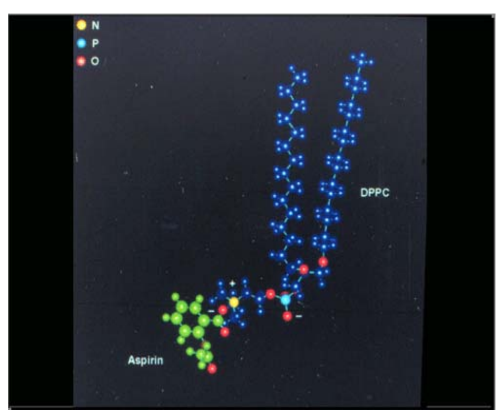
OVERVIEW

Houston-based PLx Pharma Inc., formerly GrassRoots Pharmaceuticals, is a pharmaceutical company established to utilize its patented technology to improve currently marketed drugs. It will maximize its R&D strengths to become a "license factory" that will utilize existing pharmaceutical manufacturing infrastructure to amplify the integration of its products into the market. Chairman of the Board and Chief Science Officer, **Dr. Lenard Lichtenberger,** has won two patents as a direct result of an ATP research grant in which he served as PI. His work on PC-NSAIDs, a safer and more effective form of ibuprofen and aspirin, one of the most heavily consumed over-the-counter drugs, is the company's current focus. UT-Houston's equity and royalties may be significant once the FDA grants a NDA (New Drug Application) and one or more licensing partners are found.

PROJECT BACKGROUND

Dr. Lichtenberger, professor of integrative biology and pharmacology at the University of Texas Health Science Center in Houston, has been intrigued by causes of peptic ulcer disease since his career began. NSAIDs (non-steroidal anti-inflammatory drugs), such as aspirin and ibuprofen, have gastro-intestinal side effects that cause upwards of 20,000 deaths and 100,000 hospitalizations each year in the United States alone. The objective of the ATP grant, awarded in 1995, was to develop and confirm, through laboratory studies, a new family of non-steroidal anti-inflammatory drugs (NSAIDs) that have been pre-associated with the phospholipids, phosphatidylcholine (PC) and can significantly reduce gastric erosions, the well known side-effects of the drugs. The NSAID toxicity issue was approached differently from other research projects in the past by focusing on protecting the topical surface of the gastro intestinal tract from gastric erosions caused by NSAIDs.

RESEARCH PROCESS



In 1982, Dr. Lichtenberger became intrigued with gastro-intestinal physiology and why the G.I. mucus' ability to protect intestinal tissues was not well understood. He used a materials science approach, similar to the ways the oil and gas industries have been applying surface chemistry principles to protect pipelines from corrosion, to investigate why the GI tract is able to repel acid. In the mid-1980's, The National Institute of Health, along with Nestle and the Dairy Association, began supporting an investigation into the physical chemistry of why phospholipids provide a protection barrier. In 1996, the ATP grant research began with preclinical studies to test activity of PC-NSAIDs in animal models. Based on exciting results, Dr. Lichtenberger initiated a phase 1 pilot clinical study, also under the ATP grant, with 16 healthy human subjects over a 4-day double blind, cross-over study and found the PC-aspirin compound resulted in 1/3 fewer gastric erosions than when they took plain aspirin. In 2004, Phase II clinical experiments will begin at Baylor College of Medicine. Supported by National Institute of Health, PLx Pharma and 2003 TD&T, more extensive (6 week) tests are expected to be finished by 2005. The clinical studies should provide important insight whether:

- PC-NSAIDs are safer on the GI tract than NSAIDs like aspirin and ibuprofen.
- PC-NSAIDs are more effective alone to inhibit fever, pain, inflammation and thrombus formation than NSAIDs, a patented benefit.
- PC-NSAIDs can benefit patients suffering from arthritis and prevent cardiovascular diseases such as stroke.
- PC-NSAIDs are also an alternative to Vioxx and Celebrex because Lecithin, a major component in the formulation, is recommended for patients susceptible to developing cardiac disease and atherosclerosis due to its ability to lower blood levels of cholesterol and specifically, low-density lipoprotein. Current COX-2 inhibitors like Vioxx and Celebrex are thought to increase cardiac risks.

The compound has also induced additional research to explore other potential medical benefits. New animal studies will examine the possibilities of PC-NSAIDs to aid in prevention of colon cancer, and future studies will explore the benefits for prevention of Alzheimer's disease and patient's suffering from chronic pain caused by spinal cord injury.

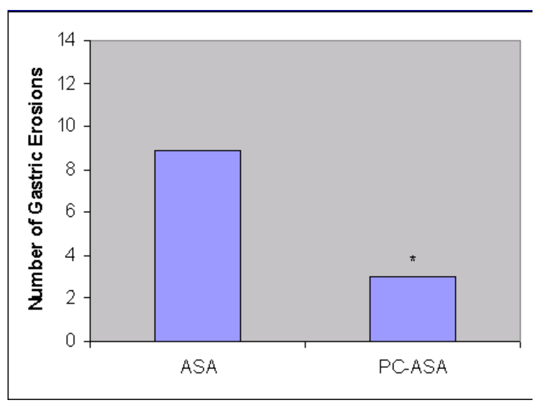


Figure 4: The Number of Gastric Erosions as Seen Under Endoscopy is Reduced 60 - 70 Percent by PC-Aspirin (PC-ASA) vs. Aspirin (ASA).

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

After unsuccessfully attempting to license the technology to a major pharmaceutical company via UTHSCH's Technology Transfer office, Dr. Lichtenberger decided to incubate the technology in a startup company called GrassRoots Pharmaceuticals in January 2003 with $500,000 in seed money from MediGen Group, a private equity firm. The company was then renamed PLx Pharma Inc.

Dr. Lichtenberger is currently chairman of the board and chief science officer of PLx Pharma. Ron Zimmerman, president and CEO of PLx Pharma has obtained over $1,500,000 in additional capital from private Texas investors, a direct result of the ATP grant. PLx Pharma Inc. provides the equivalent of two full-time jobs. Several part-time positions, including two MBA interns from Rice University and two undergraduates performing lab work, are working for the company that occupies 1000 square feet of office and lab space. Several other university professors are involved in the business, mostly as contracted researchers. If new inventions result from the recent TDT grant, other PIs may become more closely involved with the company.

A Mutual Cooperation Agreement had been signed with Nattermann Phospholipid GmbH of Cologne, Germany, providing for consolidation of a portfolio of 14 patents, some of which have since expired. PLx Pharma Inc. currently holds 7 patents, allowing for the exclusive world-wide licensing rights for the pending PC-NSAID drug. Sponsored Research Agreements have included Bayer Corporation and Cambrex, which have provided at least an additional $125,000 for research and expanded possible new drug applications for phospholipids.

Both major components of the drug are FDA approved and PLx Pharma has already obtained an FDA IND (Investigative New Drug) Application for PC-ibuprofen. After Phase III clinical trials are completed, an NDA (New Drug Application) will be filed with the FDA which will position PLx to pursue licensing agreements from pharmaceutical companies and begin collecting revenue.

LESSONS LEARNED

The project has succeeded on many levels. It has resulted in a patented new type of drug which, upon FDA approval, will compete aggressively in the multi-billion dollar pharmaceutical industry in which UT-Houston has an ownership position. PC-NSAIDs are medically advantageous to many currently available drugs including aspirin, ibuprofen, Celebrex, and Vioxx. Sponsored research agreements have set the stage for future applications for the drug which could provide even more advantages over currently available products. The class of drug also has possible applications in the fight against certain cancers, chronic pain syndrome and Alzheimer's disease.

Several companies have been formed as a direct result of the ATP grant, notably, GrassRoots Pharmaceuticals and PLx Pharma Inc. GrassRoots Pharmaceuticals, under the umbrella of PLx Pharma, is still active and approaching nutraceutical companies, which specialize in vitamins and health food, to inquire into ways to incorporate lecithin into their product lines. As part of the Advanced Learning Project at Rice University, graduate students from the Jones School of Business developed a business plan for a nutraceutical line of products. Over the last two years, four MBA graduate student interns have been conducting business modeling for PLx Pharma under the direction of President and CEO, Mr. Ron Zimmerman. PLx Pharma is currently providing the equivalent of two full time jobs and expects to expand that figure once licensing agreements are secured, expected by 2006.

Although frustrated by some unsuccessful grant proposals and the university's strained resources in providing technology transfer facilitation, the consortium of scientists is very proud of the speed at which they have progressed from a basic clinical study to a new drug application, lasting only two years. The shortened schedule has attracted students to remain in Texas to perform lab work that have foregone out of state opportunities.

Case Study Profile: Myogen, Inc.

OVERVIEW

Dr. Eric Olson, professor at the University of Texas Southwestern Medical Center, received four ATP grants related to heart failure. Results from the grants are being investigated further by Myogen, Inc., a Colorado-based biopharmaceutical company. In addition, over $1 million in licensing revenues have flowed to UT-Southwestern.

PROJECT BACKGROUND AND RESEARCH PROCESS

Heart failure affects five million Americans each year and is the major cause of death in the United States. Dr. Eric Olson, Chairman of the Department of Molecular Biology at UT Southwestern Medical Center and an international authority in the fields of muscle gene regulation, cardiac development, and signaling, determined there is a major need for new drugs to disrupt the signaling pathways underlying heart failure. Dr. Olson was awarded four ATP grants on the subject, the first in 1997. As a result of the 2001 ATP grant to identify critical targets in hypertrophic signaling pathways, Dr. Olson and his team have identified a kinase activity that is activated in response to pathologic signals that lead to cardiac growth, and discovered a cardiac-specific protein called STARS, which is induced in response to hypertrophic signals in striated muscle cells. The protein provides an important inroad into the pathway for cardiac hypertrophy.

With the eventual goal of developing pharmacologic inhibitors of hypertrophy and heart failure, several patents have been obtained from the research conducted under the series of ATP grants and an industrial collaboration was developed with Myogen Inc. Research is ongoing and in 2003, the team was awarded a fourth ATP grant to continue research on therapeutic targets for treatment of cardiac enlargement and heart failure.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

Based in Westminster, Colorado and occupying approximately 50,000 square feet, Myogen Inc. was started in 2002 by Dr. Olson and six colleagues as a biopharmaceutical company focused on the discovery, development, and commercialization of small molecule therapeutics for the treatment of cardiovascular disorders. Myogen raised $80 million in capital with its IPO, and the company, as of November 30, 2004, had a market capitalization of $290 million, an enterprise value of $171 million, and 57 employees (Stock ticker: MYOG). For the six months ended on June 30, 2004, revenues totaled $4.8 million, up from $1.4 million. Total company salaries are estimated to be between $2 million and $5 million per year. According to the PI, the ATP grants were "fifty percent responsible" for the current condition and prospects of this expanding biotechnology firm.

Currently, Myogen scientists are carrying out high throughput screens to identify inhibitors of the HDAC signaling pathway that can be used to modulate cardiac hypertrophy. While no product is currently on the market, rights to intellectual property have been licensed to Myogen, which is attempting to commercialize the technology developed during the ATP project.

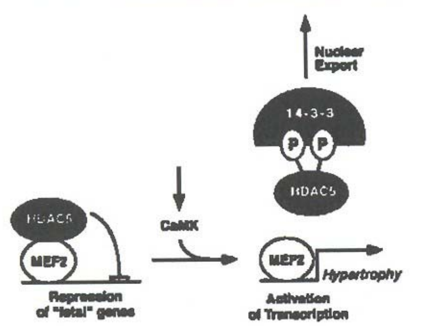


Fig. 1. A model for the control of HDAC-MEF2 interactions by CaMK signaling.

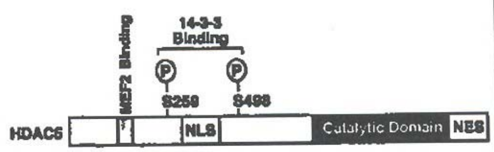


Fig. 2. Schematic diagram of HDAC5. HDAC5, like other Class II HDACs, contains a bipartite structure with an N-terminal extension and a C-terminal catalytic domain. CaMK phosphorylation sites that regulate association of HDAC5 with 14-3-3 and resulting dissociation from MEF2 are shown. Nuclear localization signal (NLS). Nuclear export sequence (NES).

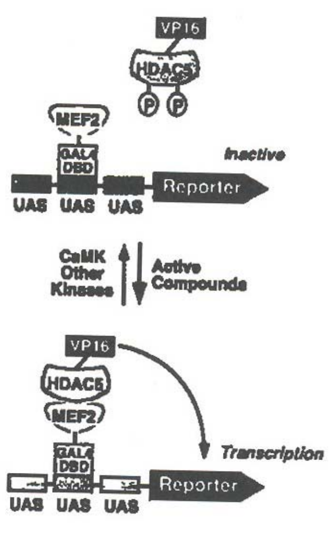


Fig. 3. Schematic diagram of assay for compounds that enhance MEF2-HDAC interactions by inhibiting CaMK or other HDAC kinases.

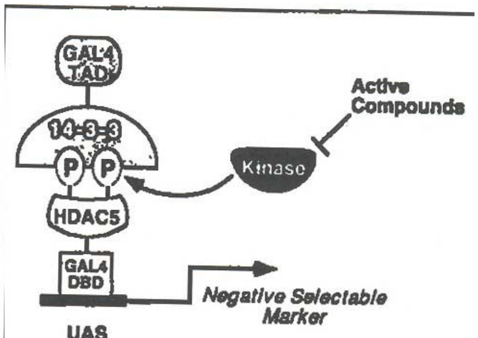


Fig 4. Schematic diagram of assay for compounds that inhibit HDAC5-14-3-3 Interactions by inhibiting HDAC kinases.

Based in part on discoveries from Eric Olson's lab in collaboration with Myogen, Novartis joined a broad research collaboration with Myogen to identify and validate drug targets for cardiac hypertrophy and heart failure. The targets will be used to design high throughput screens for small molecular modifiers of cardiac diseases. Animal models of cardiac disease in which putative drug targets have been perturbed will also be generated in Eric Olson's lab.

LESSONS LEARNED

Numerous patents have been issued and Myogen is attempting to commercialize the research results. Already, over $1 million in revenue has been received by UT-Southwestern, leveraging all four ATP grants Dr. Olson has received. The PI considers the ATP program a great success in that it has had the exact effect that was hoped for: catalyzing the industrial and academic worlds. The university has not participated directly in the commercialization process, but the school has been instrumental in assisting with the preparation of patent applications, with negotiation of royalty and licensing payments; the PI praised the school for the help it provided.

Approximately 20 graduate students and postdoctoral fellows worked in the lab during the course of the study, which provided real-world experience to strengthen the talent pool of highly trained specialists in Texas. Two post-doctorate fellows went on to be lead scientists, one for Myogen, and one for Novartis, as a result of their work on the ATP project.

Case Study Profile: GeneSwitch®

OVERVIEW

As a result of technology developed by **Dr. Bert O'Malley** under a 1999 ATP grant, a Texas start-up company, GeneMedicine, has merged with Megabios Corp. to become Valentis Inc., a publicly traded biotechnology and drug company. GeneSwitch® technology from the ATP project provides new gene therapy treatments for advanced cancers. As a result of the ATP project, approximately $4 million has been generated through licensing revenue to Baylor College of Medicine, Valentis income revenue and follow-on research funding.

PROJECT BACKGROUND AND RESEARCH PROCESS

Dr. Bert O'Malley, professor and chairman of the Department of Molecular and Cellular Biology at Baylor College of Medicine, began developing an orally regulable technology in 1992. The technology was called GeneSwitch®. In 1999 he was awarded an ATP grant to create a viral-based gene therapy system for advanced cancers in animals. If demonstrated successfully in animals, GeneSwitch® would then be tested on human subjects during clinical trials. The technique works by reducing cancer's access to blood supply at the gene level, causing the tumor to recess or even disappear.

Normally, gene therapy injections must be given once a week. With the GeneSwitch® , a single injection lasts one year and can be turned on/off repeatedly with a pill, resulting in 51 fewer injections per year for patients. The new therapy also maximizes therapeutic potential and minimizes toxicity of the therapeutic agents. By regulating the expression of erythropoietin, a promising new therapy for human anemia is being further developed through Valentis Inc. Clinical trials began in 2003.

Ligand Pharmaceuticals Inc., Gene Medicine, and Valentis Inc. have awarded over $1 million in industrial grants to the project. Other research support was received from the CaPCure Foundation ($100,000) and the National Institute of Health ($125,000). Wyeth-Ayerst Pharmaceutical, a Pennsylvania-based multinational firm, is supporting spin-off research on women's health and hormone action at $350,000 per year. The support is now in its third year.

TECHNOLOGY TRANSFER/COMMERCIALIZATION RESULTS

In 1997, Dr. O'Malley launched GeneMedicine as a result of the GeneSwitch® perfected under the ATP grant. Supporting four employees, the company merged with industrial partner Megabios Corp. in March of 1999 to become Valentis Inc. of The Woodlands, Texas. Headquartered in Burlingame, California, Valentis has a market capitalization of nearly $80 million and supports nineteen employees (NasdaqSC: VLTS). Baylor College of Medicine licensed GeneSwitch® technology to the publicly-traded company for cash and stock options worth $1 million, with additional royalties expected in the future based upon sales.

Valentis has sublicensed the technology to a number of major pharmaceutical companies including:

- Genzyme
- Glaxo Smith Kline
- Invitrogen
- LARNAX
- Lexicon Genetics
- Ligand Pharmaceuticals
- Pfizer
- Senomyx
- Wyeth

All of these companies are utilizing GeneSwitch® technology in their own research applications. The technology has also been licensed to Schering AG and Genzyme for use in development of therapeutics. To date, Valentis has received over $1 million in licensing revenue. At least three patents have been issued on the GeneSwitch® technology.

LESSONS LEARNED

As a result of a 1999 ATP grant, Dr. O'Malley's team perfected a Gene Switch technique with significant promise as a platform for a variety of gene therapy applications. The project supported four graduate students and one post-doctoral trainee, providing valuable training in the gene therapy field. While the initial Texas start-up company has merged with an out-of-state partner, licensing revenue was produced and running royalties will be flowing to the Baylor College of Medicine.

PI Name	***Project Name***	***Year***	***University Affiliation***
Aazhang, Behnaam	Development of Multiuser Transceivers for Wireless CDMA Communications	1997	Rice University
Adams, Leslie	Development and Evaluation of Live Recombinant Vaccines for Bovine Brucellosis	1989	Texas Agricultural Experiment Station
Balakotaiah, Vemuri	Novel Reactor and Catalyst Designs for Ultra-low Vehicular Emissions	2001	University of Houston
Barrera, Enrique	Containerless Processing of Nanotube Reinforced Metal Matrix Nanocomposites	2001	Rice University
Beaman, Joseph	Direct Write of Optical Components, Solid freeform fabrication, Solid Freeform Fabrication: System Integration, Selective Laser Sintering: Direct Metal Fabrication	2001,1987, 1989,1993	The University of Texas at Austin
Carney, Darrell	Thrombin Peptides as Enhancers of Tissue and Bone Healing and Inhibitors of Adhesions and Changes in Vascular Permeability	1989	The University of Texas Medical Branch at Galveston
Carole Mendelson	A Transgenic Technology Facility	1989	The University of Texas Southwestern Medical Center at Dallas
Donehower, Lawrence	Tumor Susceptible Mouse Development: Tumor Suppressor Allele Inactivation	1989	Baylor College of Medicine
Ertas, Atila	Design, Development and Construction of a New Automated Peanut Processing Facility, Development of a Proper Peanut Drying Region for West Texas and Technology Transfer	1995, 1997	Texas Tech University
Evans, Gary	Commercialization of Low-Cost Surface-Emitting Semiconductor Lasers at 1310 and 1550 nm	2001	Southern Methodist University
Freundlich, Alex	Advanced Technology Program Monolithically Integrated InP/GaInAs Multijunction Tandem Solar Cells for Space Applications	1991	University of Houston
Garry, Daniel	Molecular Characterization of Human Cardiac Stem Cells, Isolation and genetic engineering of myogenic stem cells	2001, 1999	The University of Texas Southwestern Medical Center at Dallas
Geng, Yong-Jian	Transplantation of Bone Marrow Mesenchymal Stem Cells in Dog Hearts with Myocardial Infarction	2001	UT Health Science Center at Houston
Gracy, Robert	Human Skin and Corneal Equivalents: An Alternative to Animal Testingfor Development of Pharmaceuticals for Wound Healing	1991	University of North Texas Health Science Center at Fort Worth
Gross, Guenter	A Marketable Flow Chamber for Multielectrode Recording, Optical Monitoring, and Laser Cell Surgery	1991	University of North Texas
Harbison, Karan & Barber, Suzanne	Multi-Tool Integration Kernel for Component-Based Architecture Development.	1993	University of Texas at Arlington & University of Texas at Austin
Highlander, Sarah	Pasteurella haemolytica Vaccine Strains	1997	Baylor College of Medicine
Holtzapple, Mark	Conversion of Waste Biomass to Mixed Alcohol Fuels	1997	Texas Engineering Experiment Station
Johnston, Stephen	Development of Respiratory Syncytial Virus Vaccine	1997	Southwestern Medical Center at Dallas
Killough, John	Commercialization of Parallel Reservoir Simulation	1993	University of Houston
Lichtenberger, Lenard	NSAID-Phospholipid Prodrugs: A new NSAID with Reduced GI Toxicity and Enhanced Therapeutic Activity	1995	The University of Texas Health Science Center at Houston
Manry, Michael	Integrated System for Developing Near-Optimal Estimators and Classifers	1997	The University of Texas at Arlington
Olson, Eric	Therapeutic Targets for Treatment of Heart Failure and Cardiac Enlargement	2001	The University of Texas Southwestern Medical Center at Dallas
O'Malley, Bert	An Orally-Regulable Gene Therapy for Advanced Cancers	1999	Baylor College of Medicine
Park, William	Manipulation of Grain Quality Parameters in Rice, Molecular and Genetic Manipulation of Rice Quality	1993,1995	Texas Agricultural Experiment Station
Sevick-Muraca, Eva	Polymeric Carriers for Molecularly Targeted Diagnostic Agents for Near-Infrared Optical Imaging	2001	Texas Engineering Experiment Station
Smalley, Richard	Efficient Bulk Production of Carbon Nanotubes	1995	Rice University
Varghese, Philip	Fiber-Based Fourier Transform Raman Spectrometer for Pollutant Detection	1999	The University of Texas at Austin
Wallace, Robert & Kirk, Wiley	Novel High-permittivity Gate Dielectric Materials for Advanced Microelectronics	1999	The University of Texas at Dallas & The University of Texas at Arlington
Wild, James	Development of pesticide-detection systems and appropriate detoxifying bioreactors	1987	Texas Agricultural Experiment Station
Willson, Grant	Deep UV Resists	1995	University of Houston

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Chapter 5: Interviews with Stakeholders

HIGHLIGHTS

- A sample of stakeholders was interviewed from a cross section of the industry in the state.
- Economic outcomes for directors of university technology transfer and licensing offices are stymied by a gap in funding available for prototyping and very early stage business development.
- Geographical and cultural differences significantly factionalize institutional commercialization initiatives.
- Resources dedicated to more effective direct marketing at the university level to showcase and to disseminate information about available technologies will improve financial outcomes for ATP/TDT projects.
- Significant motivation at the corporate level for sponsored research includes access to graduating student researchers.

INTRODUCTION

A parallel series of personal interviews were conducted live and by telephone with technology commercialization professionals and experts taken from a cross section of the industry throughout the state. The interviewees were drawn from three distinct communities. The selection of the groups was intended to create a sample of the "partners" whose collaborations result in the commercialization of technology in Texas. The interviews examined various aspects of commercialization patterns in the state.

One series of interviews was conducted with the directors of technology transfer and licensing offices at a representative cross section of the major research institutions throughout Texas. The directors have direct and final responsibility for technology licensing and commercialization decision making. Directors discussed various aspects of the daily operations of their offices, provided their perspectives of technology transfer as it is conducted in the state, pinpointed their involvement with the ATP/TDT program, and offered changes that could be implemented to improve statewide performance.

A second series of interviews was conducted with venture capitalists and other experts with knowledge of commercialization. The interviews honed in on several different aspects of effective commercialization of university research and development.

A third series of interviews was conducted with industrial partners, primarily in the form of corporate R&D departments, in order to determine the primary motivations for involvement of large corporations in ATP/TDT program projects.[68]

[68] The research team had planned on conducting another set of interviews with select corporate research administrators and CEOs of small technology companies, who might have been industrial partners to

5.1 University Technology Transfer and Licensing Office Directors

University Technology Transfer and Licensing Offices (TTOs) are the single point of entry internally for faculty and staff seeking advice on technology development and intellectual property resulting from their research, and externally for community and industry representatives seeking partnerships. A number of directors at the major universities across the State were interviewed in person, including:

- Lynne D. Schaefer, Director, Baylor Licensing Group, Baylor College of Medicine
- Page Heller, Director, Technology Licensing Office, Texas A&M University
- John P. Warren, Jr., Associate Vice Chancellor for Intellectual Property Management and Associate General Counsel for Research and Intellectual Property Management, University of Houston
- Peter L. Schuerman, Director, Office of Technology Transfer, Rice University
- William J. Doty, Technology Commercialization Managing Director, Office of Technology Commercialization, M. D. Anderson Cancer Center
- James C. Arie, Director, Center for Tech Development, The University of Texas Medical Branch, Galveston
- Alan H. Dean, Director, Office of Technology Ventures at the University Health Science Center, San Antonio
- Richard Leach, Director, Licensing Office, University of Texas at Arlington
- Neil Iscoe, Director, Office of Technology Commercialization, University of Texas at Austin
- Jeanette Holmes, Program Manager, Office of Technology Transfer, University of Texas at El Paso
- Lance Anderson, Director, Office of Technology Transfer and Intellectual Property, Texas Tech University
- Dennis Stone, Vice President for Technology Development, Office for Technology Development, University of Texas Southwestern Medical Center at Dallas

The ATP Program was generally recognized by TTO directors as a crucial funding mechanism by the state. Generally, ATP indirectly has allowed faculty to build expertise and to execute research. However, significant issues critical to the streamlined and efficient commercialization of university-based technology in Texas were identified by the TTO directors during interviews. Issues discussed below are neither ranked in any perceived relative order of importance nor intended to reflect the relative occurrence of repetition during the interview. In deference to the directors' nearly unanimous desire to be neither directly quoted nor paraphrased, the issues are presented in outline form only.

determine their awareness of ATP/TDT and to solicit their views about potential involvement in ATP/TDT. This task proved to be impractical. We found gatekeepers to be effective in preventing access to senior R&D officials, and several R&D staff who were contacted, proved unresponsive or were unaware of the Advanced Technology Program.

Important issues identified by the directors generally include:

- Autonomy
- Budget constraints
- Gap funding
- Metrics
- Resources for investment
- Government support
- Emigration
- Balkanization

One of the greatest barriers to successful university technology transfer is the lack of authority for directors to operate commercially with a great deal of discretion. TTO directors are essentially entrepreneurs buried in a bureaucracy, which inevitably limits their freedom and, possibly, opportunities for commercial activity. TTOs serve a facilitating function that overly burdened bureaucracy can neutralize.

University TTOs traditionally are overworked and underfunded. Not all university administrations consider technology licensing a "profit center"; in many quarters, it is strictly considered an expense. TTO budget restraints can effectively act downstream as a bottleneck for the commercialization of technology disclosed as product of ATP projects.

Beyond scientific research, the marketing research for feasibility studies is crucial to early decision making on investment in patenting costs. Larger institutions enjoy ongoing close relationships with industry and larger budgets to perform commercial research. Smaller institutions rely on in-house perfunctory market studies and outsourcing expensed against limited funds. Any initiative taken to embed in ATP/TDT awards partial corollary funding for marketing research could enhance the financial returns from ATP/TDT projects.

Texas lacks the early-stage, pre-seed funding required to move basic research from a lab prototype to an industrial prototype. Directors almost unanimously suggested that a pool of discretionary matching capital funds be provided to universities for this necessary activity. This would enable sufficient commercialization to move the technology toward the first beta customer.

Some TTO directors argued that the vast majority of ATP dollars go to funding research while support for product development is insignificant. Many prospective licensees, in contrast, are interested in more mature technologies, especially those with the potential to serve as advanced platforms. Consequently, a significant gap exists on the development side of the equation that ATP has not adequately helped erase. Some ATP-funded projects were criticized as research masquerading as technology development. Grants target research that may be promising as science, but the more appropriate target should be creating homegrown companies and not exporting technology beyond the state borders. Further, ATP/TDT funding should help to advance technologies toward a proof of principle. Scientists do basic research but funding for more development is needed if the technology is to be self-sustaining with a commercial life of its own.

Theorists commonly identify a “valley of death” that annihilates most entrepreneurs, where public remedies are not available for research transitioning to product development.[69] Unfortunately, most directors suffering from a shortage of resources view an unproven but very promising technology with a high-risk profile at the university level as little more than a bad deal. Gap funding effectively bridges that valley and is generally not attainable for TTOs seeking to commercialize ATP-funded projects. A gap funding initiative in Texas would accelerate the transition of research into market-driven products and make the costly development of product prototypes economically feasible.

Current metrics for university licensing offices are insufficient and rely on disclosures, licenses issued, patent applications, royalties earned, etc. Ironically, the industry eschews metrics more accurately reflecting a true multiplier effect in the economy, such as jobs created, marketable products introduced, and new company start-up successes that are more indicative of sustainable economic development. In effect, directors believe their offices and performance are being measured inappropriately.

If one views the primary factors for successful technology transfer as entrepreneurship, capital, and R&D, the factor most lacking in Texas is local capital formation. Because of this resource deficiency, worthwhile Texas R&D is not being developed commercially to the extent that it should. Particularly in the venture capital community, the motivation for start-up company founders to relocate to one of the coasts is strong because investors desire proximity to their investment and prefer emulsion in a culture where resources necessary to commercialization are more abundant. As more venture capital becomes available in general and through state initiatives, such as the Certified Capital Companies Program (CAPCO), these limitations may loosen.

Although science and technology agencies exist at the highest level of government administration in many states, Texas state government has had a decentralized approach to technology commercialization. Directors felt that programs elsewhere to promote technology research and development statewide might serve as models to enhance activities within Texas. They identified pioneering states as Pennsylvania, Kansas, New York, California, Oklahoma, and others.

For all its success, Texas is a net exporter of technology. More than a few promising start-up companies, early in their life cycle, emigrate to the west and east coasts, attracted by superior management expertise, more available capital, and other inducements. In many directors’ views, start-ups make a premature commitment to a corporate structure and then become anxious to emigrate to locales where greater freedom to shop for collaborative relationships and support services is possible.

Geography and cultural differences in a state as vast as Texas significantly factionalize commercialization initiatives. Although this has some benefits, more coordination and collaboration could contribute to increased commercialization of university-based

[69] http://www.rtp.org/index.cfm?fuseaction=in_the_news_item&id=209

research and technology.

Geography is a problem that affects areas of Texas disproportionately, less so in central Texas but much more so in the panhandle and in western areas of the state. The more remote areas of the state have come to rely on a "grow your own" mentality. Institutions located at a distance from the I-35 corridor face access frustrations that could be ameliorated with appropriate action at the state level of government. For example, sponsorship umbrella agreements for research could be broadened to include more remote institutions with pertinent specialties of interest. Several directors complained of favoritism, noting that some institutions "weren't getting their fair share" solely because of location. In the case of El Paso and Lubbock, valuable IP is known to cross into the bordering states of New Mexico and Oklahoma where, in some cases, better support is forthcoming.[70]

5.2 Knowledgeable Industry Experts

To obtain a different perspective on commercialization of university research and development, a number of interviews were conducted with "knowledgeable industry experts." The pool of interviewees included venture capitalists, angel investors, successful entrepreneurs, as well as non-faculty academic staff who have professional backgrounds serving as commercialization consultants in industry, including:

- Mr. Rob Adams, venture capitalist
- Mr. Clint Bybee, venture capitalist
- Mr. Wes Cole, venture capitalist
- Mr. Scott Collier, venture capitalist
- Dr. Brett Cornwell, commercialization specialist
- Mr. Wally Eater, venture capitalist
- Mr. Russ Farmer, venture capitalist
- Dr. Barbara Fossum, commercialization specialist
- Mr. Frank Gerome, venture capitalist
- Mr. Tommy Harlan, venture capitalist
- Dr. Adam Heller, entrepreneur
- Dr. John Hur, entrepreneur
- Admiral Bobby Inman, venture capitalist
- Dr. Norman Kaderlan, commercialization specialist
- Mr. Jim Ronay, commercialization specialist
- Dr. Norman Schumaker, entrepreneur
- Mr. Richard Seline, commercialization specialist
- Mr. Bruce Thornton, entrepreneur

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[70] Additional funding for promising start-up companies will be forthcoming from the Texas Certified Capital Companies Program (CAPCO). One provision will require that a portion of venture capital be directed to disadvantaged areas. See Appendix C for a further description of the Texas CAPCO.

- Dr. Raymond Yeh, entrepreneur

The general consensus among the experts was that it is very difficult to work with universities and university researchers in commercializing technology. The interviewees cited many different reasons. For example, one interviewee stressed that universities and potential licensees from the ranks of industry seek fundamentally different goals and adopt distinctly different missions:

> Both universities and industry need to admit what they are. Universities are bureaucratic agencies and industry is a capitalistic "society." Once both acknowledge what they are, what the other one is, and what that means to their own organization, then cooperation can begin.

Another interviewee thought the fundamental problem was that commercialization is an "outcome-driven" process while university personnel normally operate in a "process-driven" environment. Ponderous bureaucratic procedures necessary in a university culture are incongruous in the for-profit sector. Although all universities are criticized, public universities received the harshest criticism—a number of interviewees asserted that staff are too risk averse and avoid making decisions for which they may be later criticized. In contrast, private universities have established trustee oversight, rather than the legislative/regents oversight found in public universities. The staffs at private universities are more entrepreneurial. One interviewee opined flatly that public universities need a new mind-set to commercialize technology and that the difficulty of working with public universities has led to many potential partners avoiding them entirely.[71]

Among the experts questioned, technology transfer offices or offices of technology licensing (TTO/OTL) are considered under-staffed, and existing staff have few incentives to perform at more than a minimum performance level. The lack of incentives also hurts recruitment efforts. Several interviewees portrayed TTO staff as lacking the depth of knowledge or financial resources needed to carry out responsibilities. More importantly, TTO/OTLs are viewed as not having the necessary authority within most public universities to approve timely commercialization agreements. One individual noted that a number of years ago, 17 approvals were needed for a $300,000 license with which he was involved. This caused a nine-month delay in the licensing process.

Another expert, whose business model is formed around the commercialization of technologies developed in universities, talked at length about barriers to business. The strategy behind his business model calls for putting an umbrella agreement in place with a licensing office, clearly spelling out licensing fees and royalty streams, before any technologies disclosed at the university are reviewed for commercial potential. Even with the umbrella agreement in place, only technologies that were at least partially funded with federal grants are considered for evaluation. The rules related to commercialization of technology developed by federally funded research are well known to the company's

[71] Although public universities are considered more difficult to work with than private universities, it is considered even more difficult to conclude commercialization agreements with national laboratories.

management, but university OTL offices have been found to be too unpredictable with non-federally funded technologies. Another VC said that he does not work with universities because it "takes too much effort to finalize a deal with a university." Fortunately, among the experts interviewed, most OTLs are seen to be improving their operations in recent years. The constraints against staff and administrators are recognized, and OTLs are given high marks for doing as well as possible under difficult circumstances. Still, interviewees generally expressed a consensus that improvements were needed in (1) establishing a more formalized commercialization process (at some universities); (2) implementing a system for holding staff accountable for favorable and unfavorable outcomes typical in a commercial enterprise; and (3) perhaps, most importantly, decreasing the time needed to execute agreements.[72]

The interviewees cited other issues internal to the university as hindrances to commercialization. One interviewee who regularly works with public universities in several states said he believes there is a lack of trust between principal investigators (PIs) and OTLs. Because of PIs' lack of trust, intellectual property frequently is not disclosed to OTLs.[73]

Other barriers to effective commercialization of university R&D cited by experts included:

- Many times, a faculty and staff researcher's (PIs) primary interest is in the science, not in the development and potential applications of a technology.[74]

- PIs are primarily researchers, and they are motivated principally by the desire to secure more research funding, not to focus on applications of their research.

- PIs have few incentives to commercialize as tenure is determined primarily by research publications.

- Even when faculty and staff researchers have interest in commercialization, most do not understand how the marketplace works, how to change research direction based on market changes, and for the most part they (and students) certainly do not understand generally how to start and expand a company.

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[72] Other suggestions for change with TTOs included funding their operations using royalty streams rather than licensing fees, requiring precise outputs on an annual basis (e.g., specified number of new start-ups), and funding TTOs at a system level, instead of a campus level, in universities with multiple institutions.

[73] This interviewee also spends time with PIs trying to convince some that commercialization is not a "dirty process," but rather one that can help them achieve their societal/research/educational goals and dreams.

[74] Several interviewees believe it is impractical and unrealistic for university researchers to know what applications are likely for their R&D, and especially how large the markets may be. Only existing companies and business specialists will have a realistic understanding of the likely market acceptance of new R&D.

- Sponsored research at universities is often less effective in commercialization than that in for-profit settings because an important goal of university research is to teach students how to conduct research.

- Within many public universities, the faculty believes education is their first priority. However, research funds are an increasingly important line item in public university budgets, although few, if any, internal rewards are provided to faculty for obtaining these funds.

Some experts also viewed maturity of university R&D as a barrier, although other interviewees said that university technology, by its nature, must be early stage. Therefore, it is perfectly understandable that in research at the laboratory demonstration stage, much of the commercial potential will be a high-risk undertaking, and only a fraction of the technologies will be ready for market without further development. Because of their differing perspectives on the maturity of the R&D, commercialization partners have adopted different approaches to solving the problem inherent with early stage research. Some simply avoid university R&D entirely. Others know that they will need to devote substantial additional time, effort, and resources to university research. Others avoid incremental R&D and focus exclusively on a smaller number of high potential projects. A smaller number of more sophisticated commercial partners adopt a more seasoned approach: they follow the work of certain cutting-edge researchers, looking for clear indications of commercial potential; perhaps fund some research; and then approach the university about organizing a new venture and acquiring a license.[75]

Despite the significant corporate cultural and organizational barriers to commercialization of university R&D, the large majority of interviewees were optimistic about current trends. Many offered specific suggestions for improvement. To encourage more fruitful interactions with industry, for example, technology licensing offices were urged to collect and maintain a list of industry contacts that PIs could target as possible industrial sponsors. Suggestions were made to streamline the process of signing a deal with the university, provide a single point-of-contact for industry agents working with university researchers and technology transfer offices, and simplify mechanisms for speedier approval of the terms and conditions of specific licenses.

Other advice from these interviewees was that technology offices should focus more effort on firms and small venture capital companies that specialize in acting as intermediaries between universities and large-scale commercialization entities. According

[75] There were numerous problems cited at the operational level in performing collaborative research. These included PIs' lack of expertise in project management, problems in sharing equipment across departments, university regulations regarding visiting scientist agreements that normally give all IP to the university, and issues revolving around the change of focus as research proceeds. On the question of university research as a graduate student training ground for future scientists, there were both positive and negative responses. While some experts considered university research teams composed of graduate students inefficient, others believed the training held benefits for both the student as prospective employee and the commercialization partner as employer when the technology was eventually commercialized.

to the interviewees, many corporate R&D groups have been downsized in recent years and lack the resources, time, and ability to mine university R&D intellectual property systematically. Also, few large companies have outstanding track records of successfully launching new technologies.

The interviewees also encouraged universities to consider the longer-term economic development impacts of their R&D. Universities were advised to concentrate on more start-ups and equity arrangements and fewer front-end-loaded licenses. It was suggested also that OTLs should not be fearful of start-ups that involve faculty members. These interviewees believe most investors recognize a university's concern about losing a star researcher and that this concern is generally unfounded. Investors who regularly commercialize university R&D have the sophistication to build a management team so that a university researcher can function in a way that is supportive to the start-up, provides the researcher with personal satisfaction, but still recognizes his/her typical lack of understanding of the business world.

Finally, the interviewees encouraged universities to use alumni and others already working on behalf of the university. For example, some universities invest a portion of their funds in venture funds. The staff handling these investments, although the investments may not be in specific companies, may have additional expertise that the technology licensing office could use in their evaluations of university technologies.

Various actions were offered to improve the effectiveness and efficiency of communication process between potential investors and universities. University technology licensing offices should consider the following:

> **Portal** - Ensure that information about their technologies is sufficiently in-depth to permit adequate review online. Ideally, this will include some type of database that would allow keyword searching, despite the inherent problems in such systems.
>
> **Dissemination** - Communicate regularly, via electronic mail and other methods, with potentially interested parties about new technologies and about the latest research being performed by key faculty. Adopt a proactive approach to garner the attention of investors (MIT and Stanford were cited as doing this quite successfully). Part of this outreach effort should be devoted to identifying which university researchers have developed important intellectual property with significant commercial potential and then featuring these researchers' work with the general investment community. Universities should also consider employing representatives, or "sales personnel," who "sell" relationships and technologies. Several interviewees suggested that both a technology and a business champion are required for success. The technology champion resides within the university; the technology license office must identify the business champion outside the university.
>
> **Showcasing** - Start, or continue, technology showcases, symposiums, and even "job fair" types of forums with the purpose of introducing industry to research being

conducted at universities. Smaller universities without the scale to hold their own fairs and showcases should combine efforts to stage a larger fair. The interviewees cited a number of Texas universities as having good symposiums, as well as the National Association of Seed and Venture Funds and the Federal Laboratory Consortium for Technology Transfer forum. Recognize that technology showcases and forums help start networks and establish relationships, which may be as important as actual deals consummated in an OTL's early activities. While specific presentations may be of no interest to most attendees, they open communication channels. Also, showcase invitees should include product managers as well as researchers interested in university research products. Sometimes corporate R&D offices are as not as open to innovation as product managers within the company.

Expectations - Be realistic. Universities need to change from "selling" the next killer technology to working with investors to get a technology to the marketplace. This usually will only occur with an equitable royalty/licensing structure that is beneficial to both entities. The technology is one important piece but frequently just as important is the team that is attempting to launch it.

Celebration - Exploit commercialization successes. When there is a success, publicize it extensively, particularly among the investment community.

5.3 Corporate Industrial Sponsors

A third set of interviews was conducted with industrial partners. Deliberate efforts were made to identify the companies that had sponsored two or more projects over the course of the seven award cycles. Company representatives from industrial sponsors that have been most involved in TDT-funded projects were contacted for interviews. Due to time and budget limitations, responses were received from approximately 35 projects, or about one-fifth of all TDT projects. The distribution of most active industrial collaborators among corporations is listed in the following table.

Industrial Collaborator	***Sponsorships***
Texas Instruments	20
Semiconductor Research Corp.	7
Lockheed Martin Corp.	6
Motorola	6
3M	5
Advanced Micro Devices	5
Raytheon	5
SEMATECH	5
Borden, Inc.	4
AEL	3

Applied Materials	3
California Microwave	3
Compaq Computer Corp.	3
General Electric	3
Nokia Corp.	3
Northrop-Grumman	3
Tracor	3
Wyeth Lederle Vaccines & Pediatrics	3
ANTEK Instruments	2
Boehringer-Ingelheim KG	2
Current Technology	2
DeSmet	2
Du Pont Corp.	2
Hoechast-Celanese Corp.	2
IBM Austin Research Lab	2
Immunicon Corp.	2
Intel	2
Leica Inc.	2
Lightpath	2
Microfab	2
National Instruments	2
NCC	2
Owensboro Grain	2
Park Scientific Instruments	2
PCI Membrane Systems	2
Pratt & Whitney	2
Radiant Research, Inc.	2
Redfish Unlimited	2
Respironics Inc.	2
Rf Environmental	2
Schlumberger	2
Uncle Ben's	2
ValveTechnologies, Inc.	2
Total number of companies sponsoring 1 project	125

Multiple interviews were conducted with employees of Texas Instruments in the Dallas area, Sematech in Austin, Lockheed Martin at the company's Ft. Worth and Greenville locations, and IBM in Austin. Representatives also were contacted with Semiconductor Research Corporation in Durham, North Carolina, and with Applied Materials, Advanced Micro Devices, and Freescale Semiconductor at their Austin locations. A limited number of interviews were conducted with smaller company sponsors as well.

Motivations of the corporate sponsors were varied. Some sponsors sought applied research which could not be undertaken in-house. ("*Research can be done elsewhere and*

AMD can focus on creating products – which is what it does."[76]*)* Other sponsors indicated their primary motivation was access to research that was not a current core competency of the company. Others were seeking access to expertise, either in the form of one or more lead scientists who served as PI, or in the form of the student researchers, who, after graduation, could provide significant expertise with their newly acquired specific skills and knowledge. Other sponsors said their motivation was product development or refinement of an existing technology, and they could not divulge more because of competitive concerns. Another set of sponsors was primarily interested in access to equipment unavailable within their company, which opened opportunities for unique and advanced research. And several sponsors were most interested in monitoring cooperative research which provides companies with insight (and perhaps a head start on implementation) before academic papers are published.

A number of examples illustrate the diversity of sponsors' goals. For instance, access to graduating students clearly drives some corporate interest in sponsored research decision making. University research project experiences are recognized by industry as very desirable. As noted by one interviewee "*SRC students [those who work on Semiconductor Research Corporation-funded research projects] are worth approximately $100,000 more in industry at the start of their career due to their applicable thesis research.*"[77] A department manager at Freescale Semiconductor[78] reported that a wealth of know-how was transferred in numerous meetings with the research team during the life of the project. Four of the students were hired by the company as new employees after the research project was completed.

Another partner, Lockheed,[79] had a need to recruit new employees with experience in particular specialties in advanced materials research. From their perspective, one of the most effective methods for technology transfer is recruiting talented young graduates with newly acquired targeted skills that are directly applicable to the needs in Lockheed R&D. The company aggressively recruits students because of the expertise they acquired while participating in Lockheed-sponsored research projects.

Other benefits cited by industrial partners included acquiring greater insight into market trends and possible information about the marketing strategies that their customers were planning. One interviewee[80] pays close attention to which of his customers hire the student researchers who worked on the project he sponsored. This helps him anticipate what enhancements of products and new lines of product introduction his customers may be contemplating.

In addition to seeking information about sponsors' motivations, a limited number of sponsors were asked about their satisfaction with their sponsorships. In response to a question about whether they obtained what they had hoped, the small number of

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[76] Mr. Tim Hossain, Senior Member – Technical Staff, Advanced Micro Devices.
[77] Mr. Ralph K. Calvin, VP for Research Operations, Semiconductor Research Corporation.
[78] Mr. Hisao Kawasaki, Department Manager – CMOS Platform Reliability, Freescale Semiconductor .
[79] Mr. Terry Mize, Radar Cross Section Lead for Joint Strike Fighter, Lockheed Martin.
[80] Mr. Peter Gao, Engineering Manager, Applied Materials.

responding sponsors said "yes." One sponsor was quite enthusiastic: "*Absolutely, the work performed by Rice led to substantial breakthroughs in this area. Rice has a unique ability to not only understand the fundamental science but also to work towards practical implementation.*"

Other sponsors commented positively about their experiences in working with university researchers. A sample of the responses:

- "*Wonderful and meaningful*."
- "*Very positive, we are continuing to work with the [name of university] group in this and other areas. .... We have started another collaboration bringing them in for a Department of Energy project and discussing licensing opportunities for Rice technology*."
- "*My past experience with these researchers was extremely beneficial. As a result of the merger, my own research interests shifted (to match new corporate requirements), and I was unable to follow up consistently on this particular project.*"
- "*[Company name] has annual sales of approximately $2b per year. Several processes are used to build several products. We have used [PI name] methodology and tools in the area of amplifiers built with one of the processes. We intend to expand its use in the future.*"
- "*The benefits from the [name of university] collaboration extend across a number of areas. Not only the specific project measurement but others as well. While the project addressed [type of analysis deleted] analysis, it really dealt with development of a technology that will have applications in many other areas. [Company name] expects that the [type of market deleted] will result in a $30-40M sales growth for our company within 3-5 years. This will also result in employment of ~50-75 additional people in our Texas operations.*"
- "*In general very cooperative and interested in how the fruits of their research can become commercialized. The missions of the university and the corporation are widely disparate in the short run, but in the long term, we both have goals of improvement of our society and economy. We were fortunate in that we established very early on the expectations of each party, and we have respected those expectations over time. This is very important. When I have seen corporate/university partnerships like ours fail, it is usually due to failure of one or both sides to respect the mission of the other.*"

With respect to the TDT program in its entirety, several sponsors provided additional comments:

- "*It was very valuable to us in that it provided an incentive for the university to work with us and help us in our critical formative stages. Over the years,* *considerable resources have flowed from [company name] to [name of university], and vice versa. It has been highly advantageous to both parties. [Company name] is now cash flowing, our investors are happy, and we are positioning ourselves for attaining significant value for the investors.*"

- "*[Company name] is very proud of the relationship it has with numerous researchers at numerous research organizations. Of particular note, [company name] has had a tremendous relationship with [name of health care institution]. It is fair to say that both organizations have benefited from our collaborations.*"
- "*Assistance from the state is essential in developing world class industry relevant technologies.*"

One company respondent went to considerable lengths to describe the program's benefits, and his comments are provided in their entirety below.

> *"In the following, I am going to summarize what this program provided as benefit:*
>
> *- Training students: Our competitiveness as an industry depends very much on our ability to find qualified talent to add to our staff. In the U.S., the job of training is in the domain of universities, and the government support for these universities has been critical in providing this talent supply.*
>
> *- Direct impact on local economy: I was on the faculty at CMU, the 3rd ranked university in computer science. We probably had more talent there than UT Austin (ranked No. 7). Yet, Austin is a vibrant city with tremendous depth and breadth in the technology sector. As for Pittsburgh, I don't think we hear much coming from there? The state of Pennsylvania at the time considered investing in technology a waste of resources. Often, when a graduate student finishes the graduate degree, he or she may want to stay put in the same city (for personal reasons, for two-career issues, etc.). In Texas, a student finishing in the 3 big cities will have a lot of opportunity and thus closing the loop of training and employment within the state. Compare this to Pennsylvania, where no such support from the state exists. If you finish your degree in technology in Pittsburgh or Philadelphia you typically move out the next. I don't think this is a coincidence, but it is difficult to make a scientific analysis.*
>
> *- Sometimes, the ideas supported under programs like ATP may lead the faculty and students to consider starting companies to commercialize the technology. Naturally, they would start the company where they live, and this will add jobs to the local economies of Texas.*
>
> *- This program increases the attraction of the Texas universities in their competition nationwide for faculty recruiting. Having talented faculty is important for us in the industry, because we sometimes need consultants, and*

having a guy within a couple of miles that I can go and ask questions is tremendous for us.

- This program gives the industry access to the latest ideas in the universities through having a sponsorship, and this keeps us vital at a time when development expense has been under a tremendous pressure.

The bottom line is, when it comes to the technology sector, Austin, Dallas and Houston are now recognized centers of excellence in the same manner that Boston and the West coast are. The quality of the universities, the talent, and the overall supportive attitude of the state are all components to this success. This program is another brick in the wall of helping businesses find it more attractive to move here. I think you can make comparisons to similar programs in the states of California and Washington, and you will see the same effect. Now, business incentives alone without supporting the local talent pool do not get you very far. The state of Tennessee has been giving incredible incentives to business to move there. Guess what? Because they have no local talent there, what they end up having is carve out the low-paying jobs within the technology sector (e.g. Dell's new factory in Nashville). But the high-paying jobs, the foundation of the tax base, will likely go to California, Texas and the states of New York/Mass/and D.C. areas. It is all about talent, and encouraging this talent and maintaining it is critical".

CONCLUSION

The ATP Program was generally recognized by TTO directors as a crucial funding mechanism by the state. TTO budget restraints can effectively act downstream as a bottleneck for the commercialization of technology disclosed as product of ATP projects. Texas lacks the early-stage, pre-seed funding required to move basic research from a lab prototype to an industrial prototype. Directors almost unanimously suggested that a pool of discretionary matching capital funds be provided to universities for this necessary activity. This would enable sufficient commercialization to move the technology toward the first beta customer. Although this is not the only "gap" in commercialization, it is a significant one and one that can be addressed with relatively few, directed resources.

World-class research does not ensure world-class technologies will be commercialized in the marketplace. There are still hurdles that must be minimized to increase more effective commercialization from Texas universities in coming years. Interviewees with expertise in the field believe that interactions are improving, although they have yet to reach the levels at some private research institutions nationally. The knowledgeable industry experts provided numerous suggestions about what universities could do to improve their side of the commercialization process.

A limited sample of contacts with industrial collaborators elicited a variety of different reasons for collaborating with universities in TDT projects. These include expected commercialization outcomes as well as numerous other objectives. Funding university research gives them access to researchers and the findings of the research projects. Because qualified scientists and engineers are essential to leading technology companies' ongoing success, access to graduate and undergraduate researchers enables industry managers to 'pre-qualify' researchers. These researchers also may facilitate the transfer of technology from universities to industry in specific areas of interest to the company.

Chapter 6: Effects on Students and Educational Processes

6.1 Educational Impacts of ATP/TDT Grants

BACKGROUND

This part of the impact assessment examines the impacts of ATP/TDT grants on students and education. The original law stated, in part,

> Providing appropriated funds to faculty members of public and private institutions of higher education to conduct applied research is important to the state's welfare and, consequently, is an important public purpose for the expenditure of public funds because the applied research will enhance the state's economic growth by:
>
> ***(1) educating the state's scientists and engineers;*** (emphasis added)
> (2) creating new products and production processes; and
> (3) contributing to the application of science and technology to state businesses. [81]

Also, as noted by Reimers, "The principal contribution of a university to society and to national competitiveness today is the graduated student and, secondarily, research results that can be commercialized." [82]

The educational impacts from ATP/TDT grants were examined under five specific topics:

1. The recruitment of talented undergraduate and graduate students to Texas universities
2. The recruitment of talented faculty to Texas universities
3. Student acquisition of new, marketable skills that make a positive contribution to the science and engineering workforce in Texas
4. The retention of talented graduates (undergraduate and graduate) within the state of Texas, including the development of research positions in PI-generated startups and
5. Faculty-student interaction with on-campus programs promoting entrepreneurial activities and strengthening the educational process.

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[81] Added by Acts 1987, 70th Leg., ch. 823, § 3.08, eff. June 20, 1987.
[82] Riemers, Niels. *Best North American Practices in Technology Transfer.* Prime Minister's Advisory Council on Science and Technology, Ottawa, ON. 1998.

METHODOLOGY

Data were collected from the electronic survey of all principal investigators (PIs) and from telephone interviews with more than 200 PIs. The electronic survey focused on the recruitment and retention of students and graduates within the state of Texas. The questions focus not only on whether students remained in Texas after completing the project, but also on whether or not the project helped them gain any new, marketable skills that would subsequently make a positive contribution to the science and engineering workforce in Texas.

Exploring whether ATP/TDT research has produced any significant student/faculty interactions with on-campus programs promoting entrepreneurial activities was also of interest. Such interactions can be mutually advantageous; that is, entrepreneurial/ technology commercialization programs can encourage ATP researchers to start businesses, and ATP research can help promote entrepreneurial activities on campus.

In addition, we sought specific examples of and general views about ATP in recruitment of young faculty and students, industry involvement in educational processes, and students as agents of technology transfer upon graduation and employment in established and start-up companies.

These assessment procedure steps included:

- Developing nine questions for the electronic PI survey to help assess student and/or educational impacts;

- Exploring the topic of student and educational impacts in phone interviews with PIs and documenting the results;

- Identifying responses about names of educational and/or entrepreneurial programs on campuses that were supported or impacted by ATP/TDT research projects and conducting follow-up phone interviews for a subset of these responses; and

- Conducting an internet search for entrepreneurial-related student organizations at Texas universities that have participated in ATP/TDT grants; this led to further contact with groups at nine universities to determine potential student impacts related to ATP/TDT research projects.

As noted in a previous chapter, for the period covered by this evaluation, there were 1,854 approved ATP and TDT projects. Responses to the electronic survey represented 683 projects, or approximately 37% of the universe.

FINDINGS

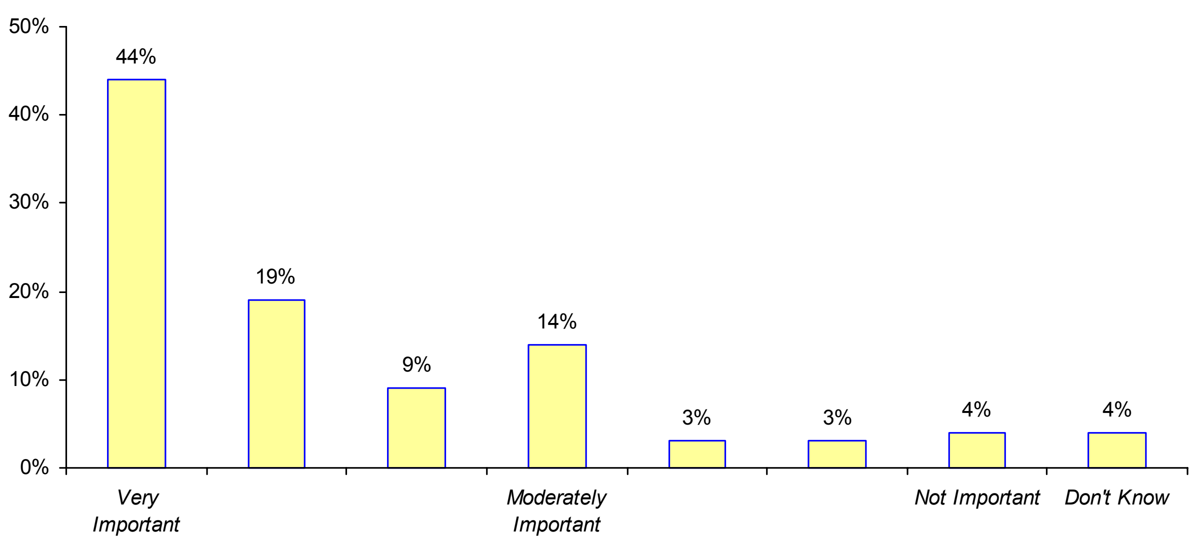
As described above, we examined five specific topics regarding the student and educational impact of the ATP/TDT programs. The data and information gathered indicate that the programs are, in fact, making significant positive impacts on all five.

1. The ATP program is having a positive impact on the attraction of talented graduate and undergraduate students to Texas universities.

One question (27A) of the electronic survey asked respondents to indicate how important the ATP/TDT grant programs are in attracting outstanding graduate students to their institution.

PIs were offered seven choices from "very important" through "moderately important" to "not important" with other possibilities situated between these choices. Another choice was "don't know." Sixty-three percent of PIs who responded to this question indicated that the grant programs were very important (6 or 7 on the 7 point scale) and 86% said they were at least "moderately important" in attracting outstanding graduate students. Only 9% of PIs felt the programs were not important and another 4% did not know. The figure below summarizes the responses.

Program's Impact on Recruiting Graduate Students



The following are quotes taken from phone interviews with PIs on the topic of the impact of the programs on student recruitment:

- A PI from the University of Texas at Pan American said, "Besides the exciting results of the [description of project] the impact on education has been amazing, starting with our current students and going to high school students that are often invited to tour [PI's] lab. Visiting high schoolers have changed their mind and have decided to enroll at UTPA in engineering fields after visiting the PI's lab and observing the research efforts and teamwork of the undergraduates."

- A Rice University PI said, "This state program allows funding to support about four to five extra students. This, in turn, has helped develop a critical mass for this research program that has attracted new students to Rice."

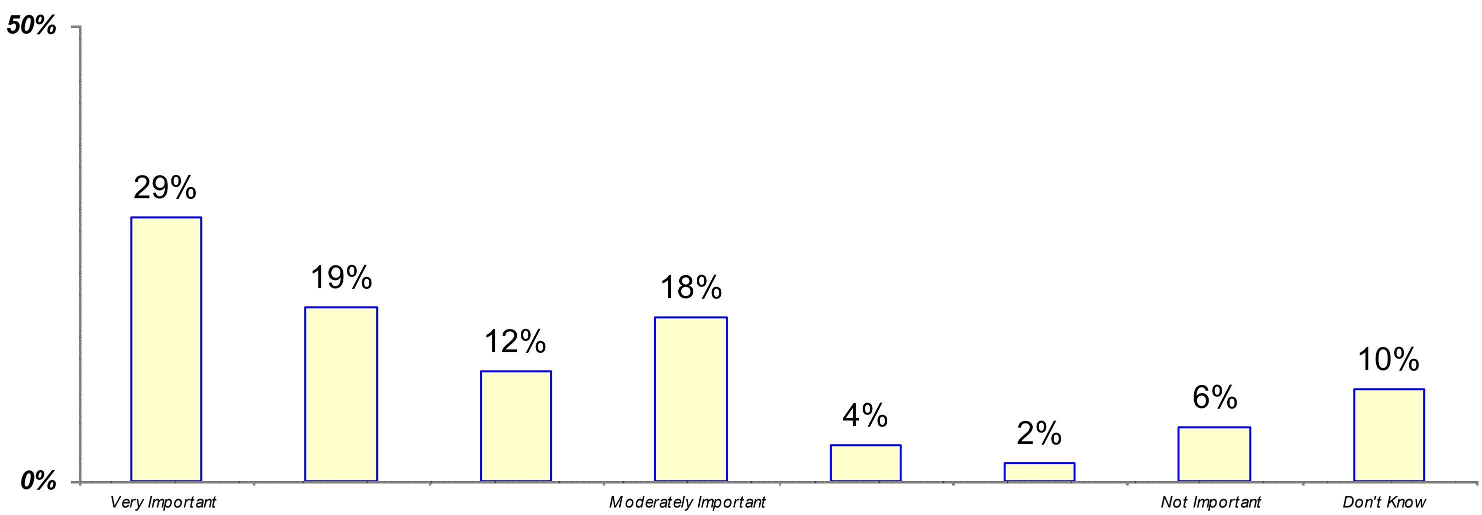
- A PI from Texas Southern University replied that, "An overview and findings from the work on my portion of the research were presented to high school students in a summer program we conduct to attract students to transportation careers."

- Another PI from Rice indicated that, "This research was a part of the [Center name]. The Center has influenced students to come to Rice."

2. The ATP program is having a positive impact on recruiting talented faculty to Texas universities

Question 27B of the electronic survey asked respondents to indicate how important the ATP/TDT grant programs are in attracting outstanding faculty to their institution. Forty-eight percent of those who responded to this question indicated that the grant programs were "very important" (6 or 7 on a 7 point scale), and 78% felt they were at least "moderately important" in attracting outstanding faculty. Twelve percent of PIs felt the programs were not important incentives for faculty and another 10% did not know. These responses are summarized in the figure below.

Program's Impact on Recruiting Faculty



This issue was addressed in two parts: (1) determining the number of students who have participated in the ATP/TDT projects; and (2) identifying knowledge and skills that students may have acquired during the course of the projects.

Question 7 of the electronic survey asked the PIs to indicate how many students (classified by level: post-doctoral, doctoral, masters, and undergraduate) worked on their projects. Based on the responses to this question, a significant number of students have been trained. The table below shows the number of projects and number of students who were involved. For instance, within this sample of all projects (683 of the 1854 funded), 270 projects employed between 1 and 3 post-doctoral individuals. Four projects employed between 4 and 9 post-doctoral individuals, and two projects employed between 10 and 19 post-doctoral individuals. The far right-hand column shows that 276 projects employed post-doctoral individuals. Likewise, 408 projects employed between 1 and 3 doctoral candidates, 60 projects employed between 4 and 9 doctoral students, and four projects employed between 10 and 19 doctoral students. A total of 472 projects employed at least one doctoral student.

Projects with Student Involvement by Level

	1 to 3	4 to 9	10 to 19	20 and more	Total Number of Projects
Post-Doctoral	270 (98%)	4 (1%)	2 (1%)	0 (0%)	276 (100%)
Doctoral	408 (86%)	60 (13%)	4 (1%)	0 (0%)	472 (100%)
Masters	277 (85%)	42 (13%)	5 (2%)	3 (1%)	327 (100%)
Undergraduate	239 (71%)	94 (28%)	4 (1%)	2 (1%)	339 (100%)

(Percentages are computed across the rows)

Other highlights of the table include:

- 327 projects or 48% of the total used masters students and 15% of these included 4 or more masters students.
- Three projects employed 20 or more masters students.
- A surprising 339 projects (representing 50 percent of the responding projects) used undergraduate students and 30 percent of these included 4 or more undergraduate students.
- Two projects employed 20 or more undergraduate students.

Question 10 of the electronic survey asked principal investigators to cite any marketable skills or competencies acquired by students who worked on their projects. The PIs provided an extensive list of technical skills in a very broad range of subject areas. Examples included:[83]

- Proficiency in selected chemistry laboratory methods
- Statistical analyses of data
- Operation of a research experiment
- Hands-on skills for Silicon CMOS foundry
- Device evaluation skills in testing
- Written and oral presentations for professional conferences
- Problem-solving abilities and presentation of the solutions in emerging areas like mobile computing
- Experimental design
- Conducting experiments using the scientific method
- Preparing research reports and articles
- Working in teams
- Medical student improved his chances of getting a competitive residency
- Independent creative thinking, work with minimal supervision
- Design, construction, operation of, and maintenance of an apparatus
- Evaluation of experimental data
- Performing an industrial hazard assessment
- Structuring ill-structured projects
- Comprehension of the limitation of technology for condition monitoring
- Comprehension of the interplay between software and hardware
- Teamwork
- Professional development
- Scheduling
- Budgeting
- Engineering design
- Knowledge of fuel systems and energy systems
- Project management
- Usability evaluation
- Technical writing
- Computer programming
- Understanding of intellectual property regulations
- Process of dealing with commercial industry
- Use of MRI in pharmaceutical evaluation

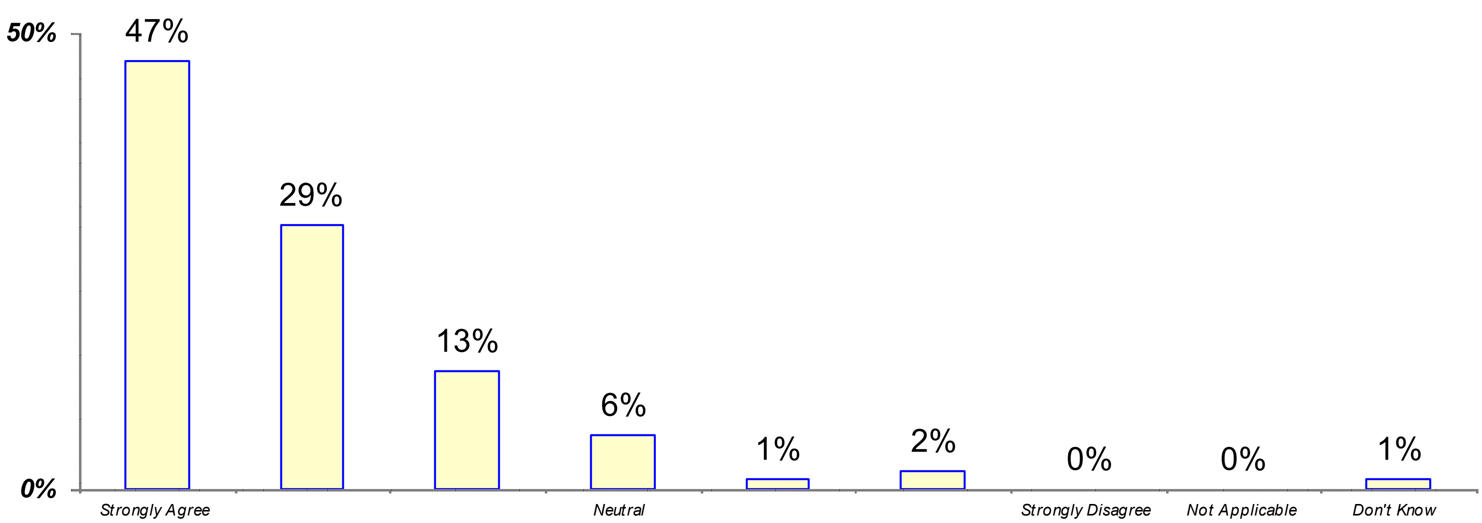
Principal investigators also noted some unique experiences, for example:

[83] Multiple responses are not indicated. For example, at least three PIs noted that experimental design was a skill their students had acquired.

- "Graduate and post-graduate researchers acquired professional grade skills in plant, cytological and molecular genetic research. Undergraduates also learned research skills. Some moved onto other things, a few moved into higher level research training."
- "Students learned how to perform mathematical modeling, and developed computational skills throughout the course of the project. They also constantly interfaced with research institutes and industrial companies, resulting in learning how to apply their skills in a business setting."
- "The students, both the graduate students and the many undergraduate students, who worked on portions of this project, acquired experience on advanced analytical and scientific techniques. For many of the undergraduates this was an unbelievable experience."
- "They learned how to design a technical project and drive it to completion. They also learned how to collaborate with industry."

A third set of data regarding this issue was obtained from question 28B, which asked PIs to respond to the statement *"ATP/TDT programs contribute significantly to producing graduates properly educated for their intended job markets and future career tracks."* To avoid bias in the question, a scale was used that allowed PIs to choose any of seven possible answers among Strongly Disagree, Neutral, and Strongly Agree. In addition, PIs were able to choose Don't Know or Not Applicable. Seventy-six percent of those who responded to this question said they strongly agreed (6 or 7 on the 7-point scale) with the statement. An additional 13% agreed with the statement. Fewer than 5% of the PIs did not agree that the ATP/TDT projects contributed significantly to producing graduates who are properly educated for their intended job markets. The figure below shows the distribution of responses.

Program Impact on Training Students



- A PI at the University of Texas Health Science Center at San Antonio said, "A former undergraduate research assistant is now finishing her second year of med school in Texas. She published a lot as an undergrad, which surely helped her get into med school."
- A University of Texas at Pan American PI said, "The results are motivating more students to inquire about opportunities to work in the nano-lab. Currently I have more than twenty-two students enrolled in different projects. Most of the research is being conducted with undergraduate students, most of whom are women and all Hispanics (including freshman). Their motivation and aspirations in the engineering field have changed significantly, given their responsibilities on the project."
- The following is from a University of Texas at Arlington PI: "The educational impact for the State of Texas is evident in the large number of students (40+) that have been trained via this project and its off-shoots."
- A University of Texas Southwestern Medical Center at Dallas PI indicated that her focus (and that of other researchers) was to train as many students as possible. At least twelve students per year during the six-years (multiple projects), or seventy-two students in total, have been trained over the years. Most of these students go on to work in various federal research programs.
- A PI from the University of Houston said, "Several students did M.A. theses associated with the project. At least fifteen students did independent study research classes supported by the project. There were several journal articles and national convention papers, each coauthored with several students."
- A Texas A&M researcher said, "The undergraduate students were doing excellent work in the classroom, and I wanted to give them the opportunity to extend their participation in the area of research as well. As a result, I have involved five undergraduate students in the research. Each undergraduate student works with one post-doc student, who is there for guidance purposes."
- A University of Texas at Dallas researcher: "One undergrad student became my technician and is now working on a project with sickle-cell anemia at UT Dallas. I talked with her supervisor recently, and she's doing great. She learned everything she knows from us."

4. The ATP Program is helping to retain talented graduate and undergraduate students within the state of Texas after graduation, including developing positions in PI-generated start-ups for their student researchers.

Question 8 of the electronic survey asked principal investigators to indicate how many graduate students, by job type (university/academic positions and business/government positions), were employed full time for more than six months in jobs located in Texas as a result of their work on their projects. A similar question (#9) asked PIs about undergraduate students.

Based on the responses to these survey questions, a significant number of students who participated in ATP and TDT projects have gone on to jobs in Texas. The nearby table summarizes the responses.

Students Who Became Employees in Texas after Project Involvement

	Graduate Students			Undergraduate Students		
	University & Academic	Business & Government	Total	University & Academic	Business & Government	Total
Total Number of Participating Students	384	507	891	197	317	514
Associated Projects	217	236	453	108	144	252
Average Number of Students Per Project	1.8	2.1	2.0	1.8	2.2	2.0

This table shows that almost 900 (891) graduate students and slightly more than 500 undergraduates took jobs in Texas in the academic, business, or government sectors, based on this sample of principal investigators. If these numbers are extrapolated to the 1,854 projects, based on the ratio of responding projects (683) to total projects (1,854), we can estimate that 2,400 graduate students and 1,400 undergraduates worked in Texas after their ATP/TDT projects. This works out to about two students per project who took positions in Texas.[84]

The following are example quotes from phone interviews with PIs on the topic of students and subsequent employment:

- A University of North Texas PI said, “Industrial plant visits of entire classes to companies involved in various ways in the project helped students to get jobs.”
- A PI from Rice University said, “As a direct result of the grant, over ten students were hired as summer interns by Nokia and/or TI. In part because of their involvement in the grant research, at least two students are now employed in Texas by Nokia and TI.”
- This is from another Rice PI: “Eight students ended up in Texas positions (two to Sun, three to TI, one to AMD, and two to IBM). The two at IBM are working on a project similar to our TDT grant research.”
- A Texas Tech PI replied, “The greatest impact of this program has been on our students. They’re working at Texas companies on fuel cells for household uses.

[84] This is a very conservative estimate. Because some PIs did not answer the two questions, it is likely that the actual number of students is much larger. For those PIs who answered, the number is about twice as high: two graduate students and two undergraduates.

We also have some students working in Austin for Motorola and AMD. These students were all bachelors and masters students, not Ph.D.s."

- A University of Texas at Arlington PI said, "One of my undergraduate students now works for a traffic management company in El Paso, Texas. Another former undergraduate student works for Northern Telecom in Dallas, Texas as a result of his work on the project. One masters and one Ph.D. student now work for a local engineering firm in Dallas as a result of their work on my project."
- A University of Texas at Austin PI replied that, "One of my Ph.D.s in chemical engineering is now a chief researcher for AMD. Another former student, who has appeared on TV and been featured in magazines, is now working on the most advanced Gate Level technology for Motorola in France. Two former students are in charge of Gate Level research at Intel. All students who have participated in this research are highly sought after in the private sector and go on to have amazing careers."
- A University of Texas Houston Health Science Center PI said, "A former student now performs risk assessment in Texas at MD Anderson. Most students are still in Texas. Only one has left the state."
- A PI from Lamar University told us, "All students are now employed. The knowledge they gained during the project was helpful in securing employment. One Ph.D. now works for Drill Quip, an oil-drilling equipment manufacturer in Houston, Texas. He developed a method for finite element modeling, the first of its kind. He presented a paper to the American Society of Mechanical Engineers and it was well received. One Ph.D. works for a company in Port Lavaca, Texas."
- A PI from University of Texas at Austin reported, "The initial studies using MPM opened the door to understanding events in T-cell biology that we continue to study today. One of the graduate students, who was part of the original MPM study, is now a post-doctoral fellow in a research lab at UT Southwestern Medical School. Another former graduate student of mine who received his masters degree from UT engineering is working on a new version of MPM. He then went on to obtain his Ph.D. here at UT Austin."

While not extensive, there are examples of students becoming involved with new start-up companies formed from intellectual property created in ATP/TDT projects.

Following are some quotations by PIs on the topic of students who worked on ATP/TDT projects and later became associated with startup companies:

- A University of Texas at Austin PI said, "One of our undergraduates went on to start his own service bureau called Harvest Technologies based in Temple, Texas. He applies the ATP technology by making machine parts in his business. The grant was essential to his startup. One of our Ph.D. students went on to work for DTM. He is now in business for himself and possibly living off royalties generated from the project. Another Ph.D. worked for DTM and now works for Solid Freeform Design in Austin, Texas."

- A Rice University PI said, “The student who started Modulus Technologies is now working on his second start-up. It’s a software company called Treligence based out of Houston, Texas. More information is available at Treligence.com.”
- A Texas A&M PI responded, “Lynn Tech may lead to commercialization of isotopes for medical purposes. One student worked at Lynn Tech before moving elsewhere. Another student is currently at Lynn Tech and is continuing the work of the former student. He has just received a Phase II grant from the NIH that he is working on.”

5. The ATP Program is helping researchers to establish interactions with on-campus programs promoting entrepreneurial activities among faculty and students and is enhancing significantly the educational process.

Of the 509 PIs who responded to the electronic survey, about one-fifth responded to question 30, which asked about any educational and/or entrepreneurial programs on campus that were supported or impacted by the ATP/TDT grant projects. About one-quarter of the PIs indicated their projects helped develop or strengthen undergraduate and/or graduate educational programs.

The following represent some examples of PI quotations on the topic of educational programs:

- A University of Texas at Austin PI said, “Undergraduate students supported by my ATP grant participated in the Undergraduate Summer Research Program here at UT.”
- From a Texas Tech PI: “Have developed a new chemistry curriculum—‘Entrepreneurial Chemistry’—which helps science (chemistry) students learn basic business skills for them to be more competitive in the job market.”
- Another Texas Tech PI said, “Students from the Howard Hughes undergraduate research program at TTU were given the opportunity to participate in a research program.”
- From a University of Texas at Arlington PI: "Much of the research funding was used to develop advanced theoretical and software tools, which are now available only at UTA. These tools can be used to further educate students.”
- A PI from University of Texas at Austin cited an example in which two graduate students were asked, through a course, to help reevaluate the market for a technology associated with a pending TDT grant. The students went on to compete in a student-run technology commercialization competition on campus. Through that effort they attracted angel funding, gained a license from the university, and are now serving as the matching funds commercial partner for the grant.

Another 25 percent of the PIs indicated that their projects helped develop or strengthen undergraduate and/or graduate courses. Comments from PIs included:

- From University of Texas at Austin: “A videoconference course was offered that involved several universities in Texas and others around the country. It was a very unique, one-of-a-kind educational experience.”
- The following is from the University of Houston: “The data volumes contributed by oil companies to support this project (eight of them) are used in our graduate and undergraduate interpretation classes, and form the basis of at least six masters and/or Ph.D. theses. More theses will follow.”
- From Rice: “This research effort was integrated into several courses. [PI’s name] teaches two graduate courses that have a strong project component.”
- A Texas A&M PI said, “We expanded the X-ray laboratory so that we could add hands-on laboratory with the x-ray lecture course.”
- A PI from University of Texas at Arlington said, “The neural networks technology developed by this project is being used in five electrical engineering courses at UTA. These courses are offered as lectures at UTA, in live TV format and also in videotape format.”

Another 25 percent of principal investigators mention special projects and/or programs affected by their projects.

- A University of Texas Southwestern Medical Center at Dallas researcher said, “The establishment of the Transgenic Technology Facility provided the equipment and personnel required to train graduate students and post-doctoral fellows in this important technology. This has, in turn, enhanced the research career opportunities of these trainees.”
- A University of Texas at Austin PI said, “During the Explore UT campus-wide open house, our lab is a major attraction. During the most recent open house, I made contact with a potential entrepreneurial collaborator, and we are in the midst of ongoing meetings to decide how to move forward.”
- An unidentified PI said, “We provided a hands-on training workshop for people from seven countries using our ATP technology coupled with funding from three federal agencies. The result was a book and three scientific publications that arose from new collaborations.”
- A University of Texas at Arlington PI said that he worked with several student organizations associated with his department, including IEEE, to get them involved in his research effort.

CONCLUSIONS AND RECOMMENDATIONS

Based on information gathered, we believe the ATP/TDT projects have succeeded in addressing a key goal of the original legislation: educating the state’s scientists and engineers. Specifically, there is substantial evidence that the ATP program has been beneficial in recruiting qualified science and engineering students to Texas universities. The vast majority (86 percent) of principal investigators believe the ATP program is at least moderately important in recruitment, and additional support comes from interview comments.[85]

The ATP program is perceived to be less important in recruitment of faculty but important nevertheless. Of the survey responses to that question, 78% felt the ATP program was very important to moderately important for faculty recruitment.

Several sources of data support the conclusion that the ATP/TDT program is having a major impact on helping student gain new, marketable skills that make a positive contribution to the science and engineering workforce in Texas. These include the large number of students who have been involved in grant projects and numerous citations of specific skills which students had learned or developed from ATP/TDT projects. Nearly 90% of PIs believe ATP/TDT projects impart skills and training that enhance students' educations and improve their job prospects.[86]

Both quantitative data and PI comments support the conclusion that the ATP/TDT Program is helping to retain talented graduate and undergraduate students within the State of Texas after graduation.

Finally, based on the electronic survey responses, phone interviews, and additional data collection, the ATP program is proving beneficial for a number of other educational processes. These include impacts on courses and curriculum, development of new centers and programs within universities, and interaction with entrepreneurial campus activities. In summary, we believe the ATP program has generated significant student and educational benefits for Texas.

6.2 Post-Project Employment Impact

HIGHLIGHTS

- A multi-step procedure was conducted to generate gross estimates of post-project employment and salary impacts for students who have graduated.
- Using survey data and reasonable assumptions for salary levels and employment tenure, a minimum post-project salary total from all projects was calculated to be $112 million. A total salary estimate based on national employment tenure figures

[85] There was no specific question on the online survey addressing undergraduate recruitment and this evaluation did not include the Summer High School Science Teacher Program. A number of PIs, however, communicated very positive experiences about this program. This anecdotal data suggests that teachers who have participated in these summer projects take the techniques they learned back into the classroom and receive an enthusiastic reception from students.

[86] As noted by Brett and Gibson, "Many companies equip university labs so that students, upon their graduation, will be familiar with the equipment and can 'hit the ground running' upon their hire by the company." Their marketability also increases due to exposure to, and involvement with, industry partners. Brett, A., Gibson, D., and Smilor, R., *University Spin-Off Companies*, chapter 5, p. 115, Rowman & Littlefield (January 1991).

was calculated to be $516 million.
- Cautions and limitations about the estimates are provided, but it is clear that post-employment salary impacts have been significant.

We undertook a multi-step process to assess the post-project employment and salary impacts for students who worked on ATP/TDT projects. The first step was to determine the number of graduate and undergraduate students, based on questions from the survey of principal investigators. The second step identified salary levels for the different groups of students. A third step examined the length of time students were employed after graduation. Finally, estimates were developed for two scenarios, and some limitations are offered.

Two questions related to student employment were asked on the survey instrument.

> "How many *graduate* students were employed full time for more than six months in jobs located in Texas as a result of their work on your project?"

The second question was identical except that it asked about *undergraduate* students. The PIs were asked to provide numbers for university/academia positions and for private/government positions. For the 683 projects, a total of 1,410 students were identified. This total included 891 graduates (384 in university/academia and 507 in private/government) and 519 undergraduates (197 in university/academia and 322 in private/government). These were students who had worked on the ATP/TDT projects and who were employed at least six months in Texas as a result of their work on the projects.

A second step in this estimation process required determination of salary levels. Due to the wide ranging fields of research covered by the ATP/TDT projects, salary figures were used for research & development scientists and engineers. Within this category, average salary levels are available for those with bachelors, masters and doctoral degrees. (For the graduate salary, the mean of masters and doctoral salaries was used.)

The projects in this study were those awarded in odd years between 1987 and 2001. To adjust the salaries for inflation, the employment responses were divided evenly between the project award year and the following year. An assumption was made that the first year of employment was the year following the award cycle--for example, 1988 for those researchers working on 1987 projects. Assuming that salary changes correspond to changes in the Consumer Price Index (CPI) over the 15-year period, the 2002 salaries (graduate: $75,109; undergraduate: $57,741) were adjusted downward by changes in the CPI to compute the gross salaries for each year from 1988-2003.

Two other assumptions were made. The first was that the Texas salaries were comparable to the national salary averages for research & development scientists and engineers.[87]

[87] A comparison of salaries in the same job codes for Texas and the national average showed variation of ± 6%. Therefore this assumption appears reasonable.

Also, because of data limitations, it was assumed that the salaries, whether employed in university/academia or private/government, were the same.

A third step in the process was to determine employment tenure estimates or the length of time that an employee stays in his/her position. Figures are available from the U.S. Department of Labor - Bureau of Labor Statistics on the average amount of time spent in a job by an employee's age.[88] The 20- to 24-year age range was used for the undergraduate tenure and the 25- to 34- year age range was used for graduate employee tenure. These numbers are 1.3 years and 2.9 years, respectively. The survey question asked only if the student worked at least six months; thus, a six-month employment tenure figure was used as the lower bound for both graduates and undergraduates.

Once all three components had been estimated, the computation was straightforward. If one assumes that all students worked for six months, their total salaries would have been $41.4 million. Using the national average tenure for all jobs, their salaries would have been $189.9 million. These amounts are based solely on the responses to the survey, which comprise approximately 36.8% of all ATP and TDT projects funded to date. The survey responses, as noted in Chapter 2, are representative of all projects. Thus, it is possible to compute an estimated number of students and salaries for *all projects,* not just those responding to the survey. To compute the estimate for all projects, the initial salary totals ($41.4 million for six months and $189.9 million for the longer tenure) may be multiplied by a factor of 2.72 (1 / 0.368 = 2.72). Therefore, the total number of graduate students with post-project employment was about 2,423 (891 X 2.72 = 2423) and the number of undergraduates was 1,412 (519 X 2.72= 1,412). The estimated salaries for six months are $112.6 million ($41.4 X 2.72), and the estimated salaries using the national averages for employment tenure are $516.5 million ($189.9 million X 2.72).

LIMITATIONS AND CAUTIONS

Despite the wording of the survey question, which asked principal investigators to identify employment entirely attributable to a research project, it is probable that some proportion of these researchers would have been employed in Texas after they graduated even if they had not worked on the project.[89] What is not clear is how soon after graduation they would have been employed or what type of position they would have secured were it not for their experiences related to the research project. Also, there were

[88] This information is available only for all occupations, not just scientists and engineers.

[89] The number of graduate students represents about 25% of all graduate students working on ATP/TDT projects, and the number of undergraduate students represents about 36% of all undergraduate students working on the projects. While the undergraduate proportion seems somewhat high, it would be expected that more undergraduates than graduates would remain within the State of Texas. Also, the assessment team's estimate of the number of undergraduates who worked on all projects is about 40% lower than an estimate compiled by the Higher Education Coordinating Board from reports from PIs. If that higher number were the denominator, then the proportion of undergraduates decreases to 22%. Although we have no benchmark for these proportions, they seem reasonable.

numerous examples provided by PIs in the ATP and TDT telephone interviews of their students taking positions with industrial sponsors and companies in related fields.

There are potential problems in other components of the estimation process. Because no tenure data are available for science and engineering job codes, or for college graduates for that matter, we had to rely on median tenure figures by age group. Further, there may be biases introduced by our assumption that wages for scientists and engineers working in academia/government and private industry are the same. All of these suggest caution in interpreting the results. However, it is clear that even if the numbers are reduced by half, the post-employment economic impacts have been substantial.

	Tenure		Jobs				Salary - Tenure based on age				Salary - 6 month tenure			
Year	**25-34 yrs**	**20-24 yrs**	**Graduates**		**Undergraduates**		**Graduates**		**Undergraduates**		**Graduates**		**Undergraduates**	
	Grad.	**UG**	**Acd./Govt.**	**Private**	**Acd./Govt.**	**Private**	**Acd./Govt.**	**Private**	**Acd./Govt.**	**Private**	**Acd./Govt.**	**Private**	**Acd./Govt.**	**Private**
1988	2.9	1.3	10.5	22.5	4.5	9	$1,443,640	$3,093,513	$213,217	$426,435	$248,903	$533,364	$82,007	$164,013
1989	2.9	1.3	10.5	22.5	4.5	9	$1,505,945	$3,227,026	$222,420	$444,839	$259,646	$556,384	$85,546	$171,092
1990	2.9	1.3	24.5	32	8	21.5	$3,691,751	$4,821,878	$415,429	$1,116,465	$636,509	$831,358	$159,780	$429,410
1991	2.9	1.3	24.5	32	8	21.5	$3,902,618	$5,097,297	$439,158	$1,180,236	$672,865	$878,844	$168,907	$453,937
1992	2.9	1.3	17	26.5	6.5	32	$2,826,898	$4,406,635	$372,490	$1,833,799	$487,396	$759,765	$143,266	$705,307
1993	2.9	1.3	17	26.5	6.5	32	$2,914,637	$4,543,404	$384,051	$1,890,715	$502,524	$783,346	$147,712	$727,198
1994	2.8	1.2	22.5	40.5	14	23.5	$3,839,526	$6,911,146	$787,121	$1,321,239	$685,630	$1,234,133	$327,967	$550,516
1995	2.8	1.2	22.5	40.5	14	23.5	$3,940,422	$7,092,760	$807,805	$1,355,959	$703,647	$1,266,564	$336,586	$564,983
1996	2.7	1.1	19.5	36	15	15.5	$3,389,115	$6,256,828	$816,521	$843,738	$627,614	$1,158,672	$371,146	$383,517
1997	2.7	1.1	19.5	36	15	15.5	$3,492,232	$6,447,198	$841,364	$869,409	$646,710	$1,193,926	$382,438	$395,186
1998	2.6	1.1	30.5	38.5	13.5	22.5	$5,383,426	$6,795,472	$775,010	$1,291,683	$1,035,274	$1,306,821	$352,277	$587,129
1999	2.6	1.1	30.5	38.5	13.5	22.5	$5,468,606	$6,902,995	$787,273	$1,312,121	$1,051,655	$1,327,499	$357,851	$596,419
2000	2.7	1.2	37	35	23.5	20	$7,044,793	$6,663,994	$1,528,787	$1,301,096	$1,304,591	$1,234,073	$636,995	$542,123
2001	2.7	1.2	37	35	23.5	20	$7,289,829	$6,895,785	$1,581,963	$1,346,351	$1,349,968	$1,276,997	$659,151	$560,980
2002	2.9	1.3	30.5	22.5	13.5	17	$6,643,347	$4,900,830	$1,013,355	$1,276,076	$1,145,405	$844,971	$389,752	$490,799
2003	2.9	1.3	30.5	22.5	13.5	17	$6,794,752	$5,012,522	$1,036,449	$1,305,158	$1,171,509	$864,228	$398,634	$501,984
Totals	-	-	384	507	197	322	$69,571,536	$89,069,282	$12,022,413	$19,115,320	$12,529,845	$16,050,945	$5,000,014	$7,824,593

Total Number of Jobs: 1410 **Tenure Based Salaries: $189,778,551** **Six Months Salaries: $41,405,397**

Data Sources:

Scientist and Engineer Salaries: "R&D Salaries Grow Despite Economic Doldrums," R&D Industry Guide – August 2003 – July 2004, R&D Magazine, pp. 9 http://www.rdmag.com/pdf/industryguide/RD03SurveyREV.pdf

Texas and National Salaries: U.S. Department of Labor, Bureau of Labor Statistics, "Occupational Employment and Wage Estimates," http://www.bls.gov/oes/oes_dl.htm

Tenures: U.S. Department of Labor, Bureau of Labor Statistics, Table 1. "Median years of tenure with current employer for employed wage and salary workers by age and sex, selected years, 1983-2004," http://www.bls.gov/news.release/tenure.t01.htm

Consumer Price Index: U.S. Department of Labor, Bureau of Labor and Statistics, "U.S. All items, 1982-84=100," http://data.bls.gov/cgi-bin/surveymost?

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Chapter 7: Benchmarking Analysis

7.1 Science and Technology Workforce in Texas

HIGHLIGHTS

- When the science and technology workforce of Texas is benchmarked against 13 other states, in both point-in-time and longitudinal comparisons, Texas' ranking is sub par.
- For some indicators, Texas has actually declined in per capita terms over the past 10 to 15 years. And comparisons with other states reveal that Texas ranks far below leader states such as California, New York, Colorado, Minnesota, and Maryland.
- Considerable advancement is needed if Texas' science and engineering workforce is to be among the national leaders.

BACKGROUND

One of the central goals of the ATP program has been to strengthen the State's scientific and technological workforce by increasing the supply of engineers and science graduates, with the broader objective of fostering economic growth and new science and technology industries. In this section, Texas' science and technology workforce is compared with that of thirteen other states based on a variety of science and technology indicators. In addition, several different workforce indicators were traced from around 1985 (based on data availability) to 2001. The states selected for comparison are: Massachusetts, Oregon, California, New York, Colorado, Maryland, Georgia, Minnesota, North Carolina, Florida, Pennsylvania, Virginia, and Arizona. The selected states fall into two categories: 1) leader states (Massachusetts, California, Colorado, Maryland, Minnesota, North Carolina, Virginia, and Oregon), which have made well-known, well-documented efforts to build a large science and technology workforce; and 2) peer states (New York, Georgia, Florida, Pennsylvania, Arizona), often used for comparisons and benchmarking studies involving Texas. All of the cited data are derived from federal government agencies. Data from 1993-2001 were extracted from the State Science and Technology Profiles compiled by the National Science Foundation every two years.

POINT-IN-TIME STATE RANKINGS

In March 2004, the Milken Institute, a California-based organization specializing in U.S. and world market developments and economic trends, released its State Science and Technology Index.[90] The Milken Institute released an earlier version of the index in

[90] DeVol, Ross and Rob Koepp, *State Science and Technology Index: Enduring Lessons for the Intangible Economy. Santa Monica, CA: The Milken Institute, 2004*. Online. Available at: http://www.milkeninstitute.org/publications/publications.taf?function=detail&ID=304&cat=ResRep

2002. The purpose of the study is to measure and contrast each state's inventory of technology and science assets, which can be leveraged to promote economic development. Seventy-five separate measurements were employed in compiling the State Technology and Science Index. The measurements were grouped into five categories: research and development; entrepreneurial activity, education, concentration of scientists and engineers, and the prominence of the tech sector in the business community. Each state was given an overall ranking and was also ranked separately for its performance in each of the five categories. As in the 2002 study, the 2004 survey revealed a direct relationship between the state index scores and per capita income.[91] The underlying premise is that the greater a state's investment in technology and development of technology businesses, then the greater the benefit to its citizens.

The same five states occupied the top and bottom ranges of the rankings in 2002 and 2004, though not in the same order. The top five, in both years, included California, Massachusetts, Colorado, Maryland, and Virginia. The bottom five included Mississippi, Arkansas, South Dakota, West Virginia, and Kentucky. In 2004, Massachusetts ranked first, above California (#2) and Colorado (#3) on the index. Mississippi dropped below Arkansas (#49) for last place. In the 2002 ranking, Arkansas placed last, while Mississippi was 49th.

In the overall rankings, Texas's position dropped nine places from 2002 to 2004. When compared with the other thirteen states examined, Texas placed near the bottom of the list.

Overall Ranking, Technology and Science Assets

State	Rank (2004)	Rank (2002)	Rank Change	Score (2004)
Massachusetts	1	1	0	84.35
California	2	3	1	78.86
Colorado	3	2	-1	78.77
Maryland	4	4	0	78.19
Virginia	5	5	0	72.27
Minnesota	8	10	2	67.49
New York	15	12	-3	60.66
Pennsylvania	16	16	0	60.36
Arizona	18	18	1	58.47
Georgia	18	15	-3	58.10
Oregon	19	23	4	57.76
North Carolina	20	17	-3	57.28
Texas	**23**	**14**	**-9**	**54.91**
Florida	32	29	-3	44.47

Source: *State Science and Technology Index 2004*, Milken Institute, p. 2.

[91] Ibid, p. 7.

In order to measure workforce development, the State Science and Technology Index looked at two types of indicators: human capital investment, and the concentration of scientists and engineers in the state. Human capital investment contained educational attainment indicators such as the number of doctoral scientists and engineers, the number of science and engineering bachelors, masters and Ph.D. degrees granted, as well as other educational indicators, such as state appropriations for higher education and financial aid.[92] Texas ranked 38th overall on the human capital investment index.

Human Capital Investment Ranking

State	Rank (2004)	Rank (2002)	Rank Change	Score (2004)
Colorado	1	2	1	78.11
Minnesota	2	5	3	76.78
Massachusetts	3	1	-2	73.78
Maryland	4	3	-1	73.56
California	7	4	-3	67.11
New York	10	13	3	64.44
Virginia	14	13	-1	62.44
Oregon	20	27	7	57.67
Pennsylvania	24	21	-3	52.11
North Carolina	33	25	-8	44.44
Arizona	35	29	-6	43.33
Texas	**38**	**36**	**-2**	**40.67**
Georgia	43	41	-2	35.11
Florida	44	41	-2	34.89

Source: *2004 State Science and Technology Index 2004*, Milken Institute, p. 62.

In the category of technology and science workforce, measuring the state's concentration of scientists and engineers, Texas ranked considerably higher, at #8 overall.

[92] All of the educational attainment figures used by the Milken Institute came from the same National Science Foundation data cited in the longitudinal study below.

State Concentration of Scientists and Engineers

State	Rank (2004)	Rank (2002)	Rank Change	Score (2004)
Massachusetts	1	3	2	89.00
Maryland	2	1	-1	86.11
California	3	2	-1	83.56
Virginia	4	4	0	81.56
Colorado	5	5	0	78.78
Texas	**8**	**7**	**-1**	**71.56**
Arizona	10	10	0	66.22
Georgia	11	12	1	65.44
Minnesota	13	11	-2	64.67
North Carolina	16	13	-3	62.11
Pennsylvania	18	15	-3	61.33
New York	20	16	-4	60.44
Oregon	24	24	0	53.89
Florida	27	21	-6	52.22

Source: *State Science and Technology Index 2004*, Milken Institute, p. 63.

The Milken Institute determined the concentration of scientists and engineers in a state by calculating the percent share of employment in high technology industries as they relate to the state's total employment.

In 1999 and 2002, the Progressive Policy Institute, a Washington, D.C. organization, published its State New Economy Index.[93] The index applies key measures of the New Economy to the state economies, employing seventeen indicators divided into five categories: 1) knowledge jobs, 2) globalization, 3) economic dynamism and competition, 4) the transformation to a digital economy, and 5) technological innovation capacity. Science and technology workforce development was included in the "knowledge jobs" category, which measured the percentage of jobs in offices; the percentage of jobs held by managers, professionals, and technicians; and the educational attainment of the workforce.[94]

In 1999, the overall knowledge jobs index ranked Texas 32nd out of 50 states. When compared with the 13 other states examined, Texas ranked 13th out of 14.

[93] The Progressive Policy Institute, *The 2002 State New Economy Index*. Washington, DC, 2002. Online. Available at http://neweconomyindex.org/states/ See also: The Progressive Policy Institute, *The 1999 State New Economy Index*. Washington, DC, 1999. Online. Available at http://www.neweconomyindex.org/states/1999

[94] Workforce data used to construct the indicators was drawn from the Bureau of Labor Statistics and the U.S. Census Bureau. Data on educational attainment came from the NSF State Science and Engineering Profiles and the U.S. Census Bureau.

Knowledge Jobs Index 1999

State	Rank	Score
Massachusetts	1	11.48
Colorado	3	9.08
Virginia	5	8.15
New York	6	8.15
Minnesota	7	8.11
Maryland	8	8.08
California	10	7.95
Arizona	15	7.02
Florida	18	6.75
Oregon	22	6.21
Pennsylvania	24	5.87
Georgia	25	5,83
North Carolina	31	5.23
Texas	**32**	**5.17**

Source: Progressive Policy Institute, New Economy Index 1999.

In 2002, the overall knowledge jobs index ranked Texas 21st out of 50 states.

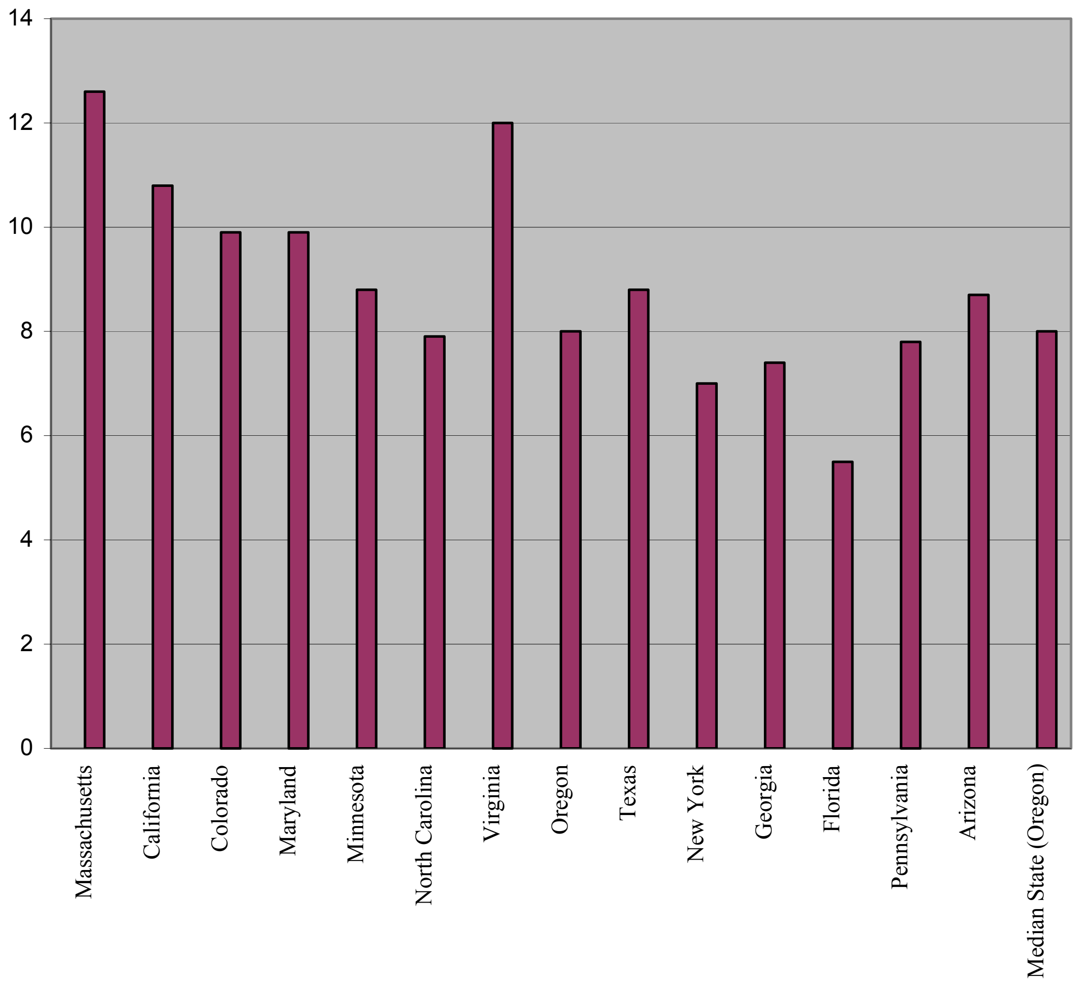
Knowledge Jobs Index 2002

State	Rank	Score
Colorado	1	15.15
Maryland	2	14.78
Massachusetts	3	14.59
Virginia	4	13.33
Oregon	7	12.63
Minnesota	9	12.39
California	10	11.92
New York	11	11.80
Pennsylvania	18	10.42
Texas	**21**	**10.20**
North Carolina	30	9.45
Florida	31	9.36
Georgia	32	9.35
Arizona	33	9.22

Source: Progressive Policy Institute, 2002 New Economy Index, p. 13.

Two employment indicators also were benchmarked. Massachusetts ranked first among all peer states in the proportion of state employment in high-tech NAICS codes. Approximately one of every eight Massachusetts employees (12.6%) of its total employed population are in high-tech, while in Virginia it was 12%, in California (10.8%) and Colorado 9.9%. Texas with 8.8% ranked above the median state, Oregon, which reported 8%, and ahead of six peer states.

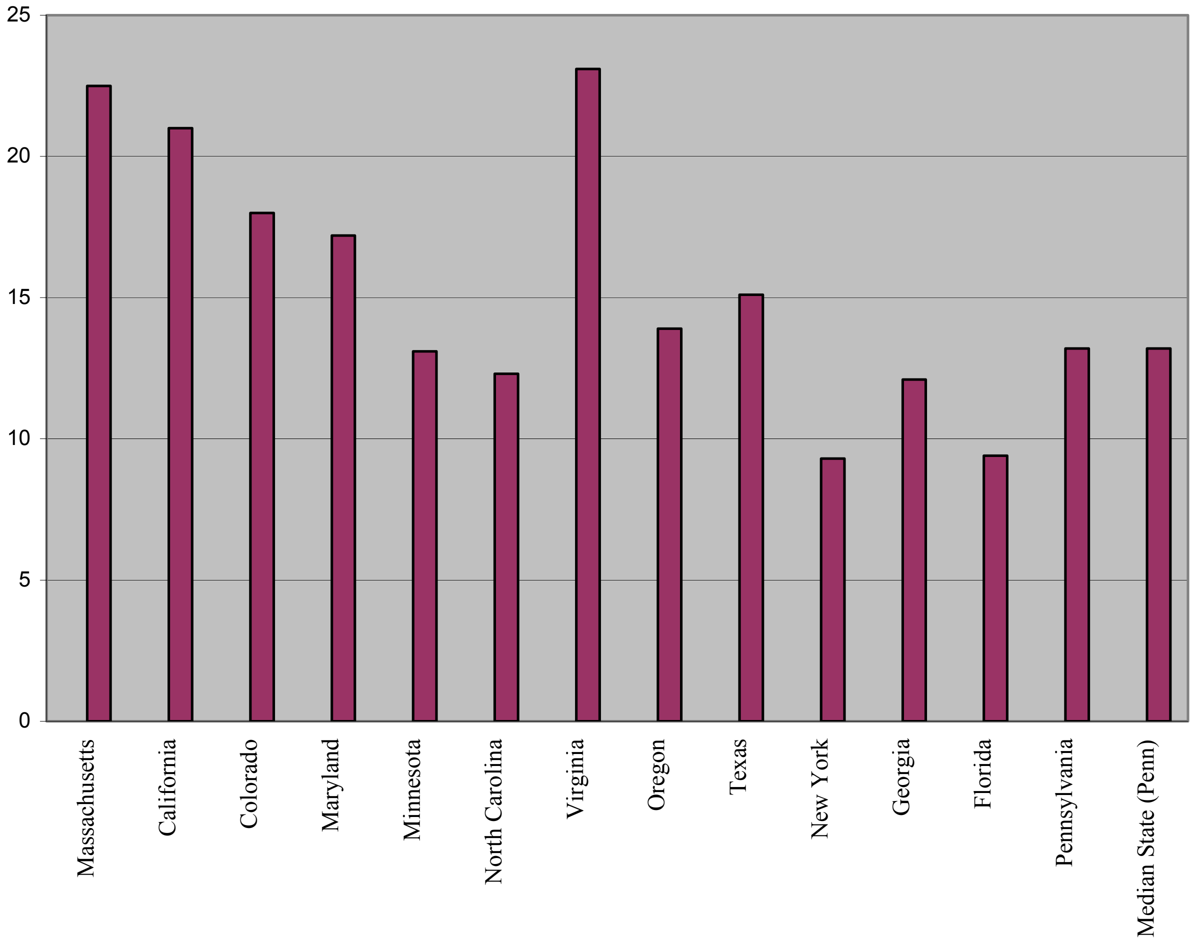
Percentage of Employment in High-tech NAICS Codes



Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

In a measure of the proportion of a state's payroll in the high-tech NAICS codes, Virginia ranked first with 23.1% of its total payroll. Massachusetts and California followed closely at 22.5% and 21% respectively, with Colorado and Maryland also ranked highly. Texas ranked higher than the median state (Pennsylvania) with 15.1% of its payroll in high-tech NAICS industries and ahead of seven peers.

Percentage of Payroll in High-tech NAICS Codes



Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

LONGITUDINAL TRENDS

Total number of doctoral scientists and engineers, 1993-2001[95]

This indicator measures the number of graduate degree recipients (excluding M.D.s) in science and engineering fields, including health fields, working in the state. In the

95 National Science Foundation, Division of Science Resource Statistics. *State Science and Engineering State Profiles.* (Washington, DC*)* Online. Available at: http://www.nsf.gov/sbe/srs/sepro/start.htm. Accessed February, 2004. percent of workforce figures were derived by dividing the state total by the total civilian labor force for the state, for the corresponding year. State labor force totals are from U.S. Department of Labor, Bureau of Labor Statistics. State and Regional Unemployment, Annual Averages. Annual averages by state, 1970-2003 available online at: http://www.bls.gov/lau/staadata.txt.

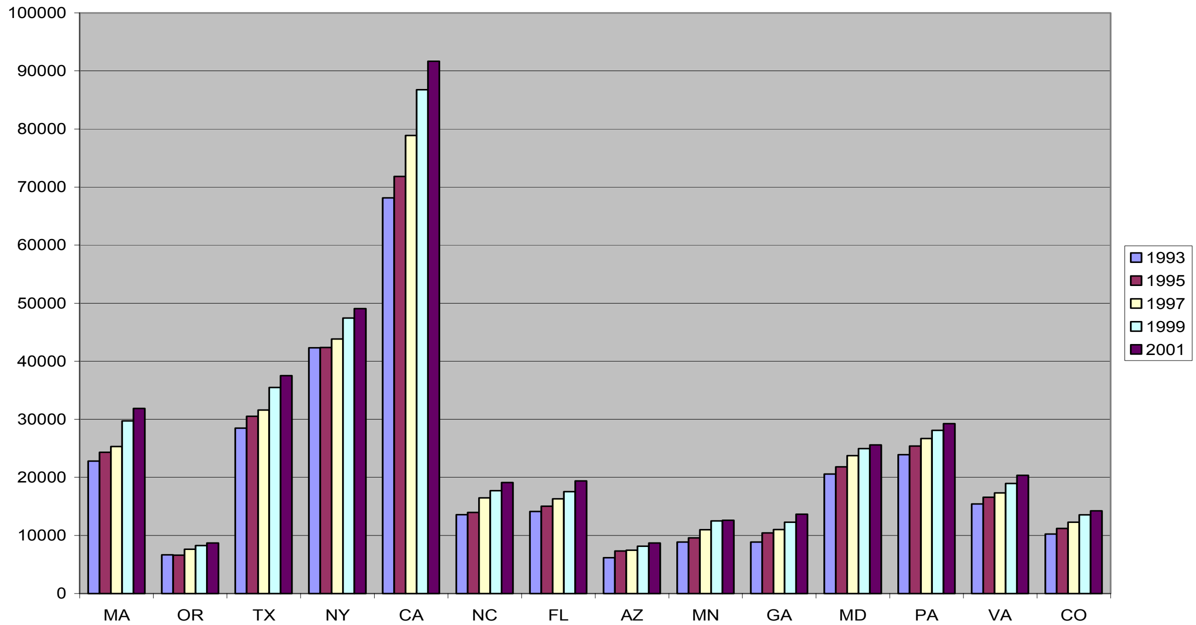
ranking of overall totals of doctoral scientists and engineers per state, Texas consistently ranked third, behind only California and New York. However, this ranking may be due to Texas' high population relative to the other 13 states, rather than an especially high concentration of trained scientists and engineers.

State Rankings for Number of Doctoral Scientists and Engineers

	1993		2001		
1	CA	68,137	CA	91,690	
2	NY	42,292	NY	49,100	
3	**TX**	**28,507**	**TX**	**37,520**	
4	PA	23,898	MA	31,860	
5	MA	22,811	PA	29,280	
6	MD	20,597	MD	25,590	
7	VA	15,432	VA	20,360	
8	FL	14,148	FL	19,410	
9	NC	13,577	NC	19,120	
10	CO	10,241	CO	14,220	
11	MN	8,868	GA	13,640	
12	GA	8,867	MN	12,630	
13	OR	6,660	AZ & OR	8,720	(tie)
14	AZ	6,172			

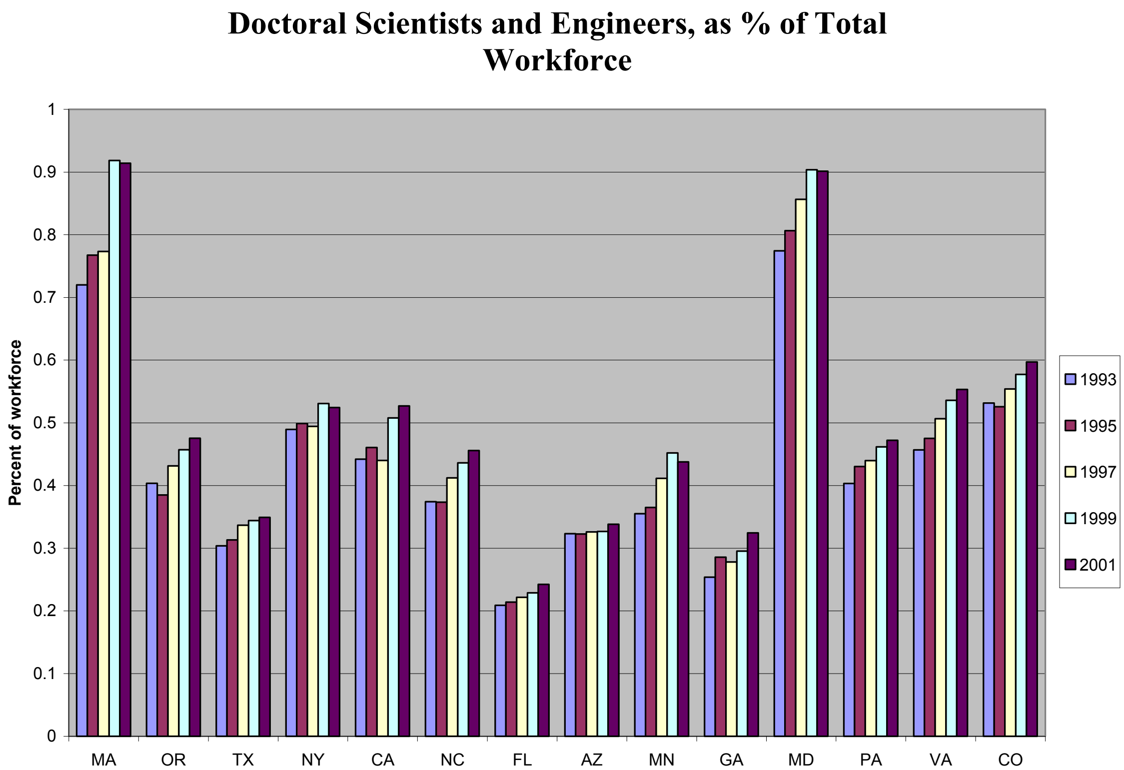
When the number of doctoral scientists and engineers is computed as a percentage of the total civilian state workforce, Texas consistently had a much lower percentage than all of the "leader" states. Texas also ranked below Pennsylvania, a peer state, every year. Texas did not experience any dramatic growth in the percentage of workforce consisting of doctoral scientists and engineers between 1993 and 2001, though there was a negligible increase.

Total Number of Doctoral Scientists and Engineers, 1993-2001



State Rankings for Number of Doctoral Scientists and Engineers, as Percentage of Total Civilian Workforce

	1993		2001	
1	MD	0.774	MA	0.914
2	MA	0.720	MD	0.902
3	CO	0.532	CO	0.597
4	NY	0.490	VA	0.553
5	VA	0.457	CA	0.527
6	CA	0.442	NY	0.525
7	OR	0.404	OR	0.475
8	PA	0.403	PA	0.472
9	NC	0.374	NC	0.456
10	MN	0.355	MN	0.438
11	AZ	0.323	**TX**	**0.349**
12	**TX**	**0.304**	AZ	0.338
13	GA	0.254	GA	0.295
14	FL	0.209	FL	0.242

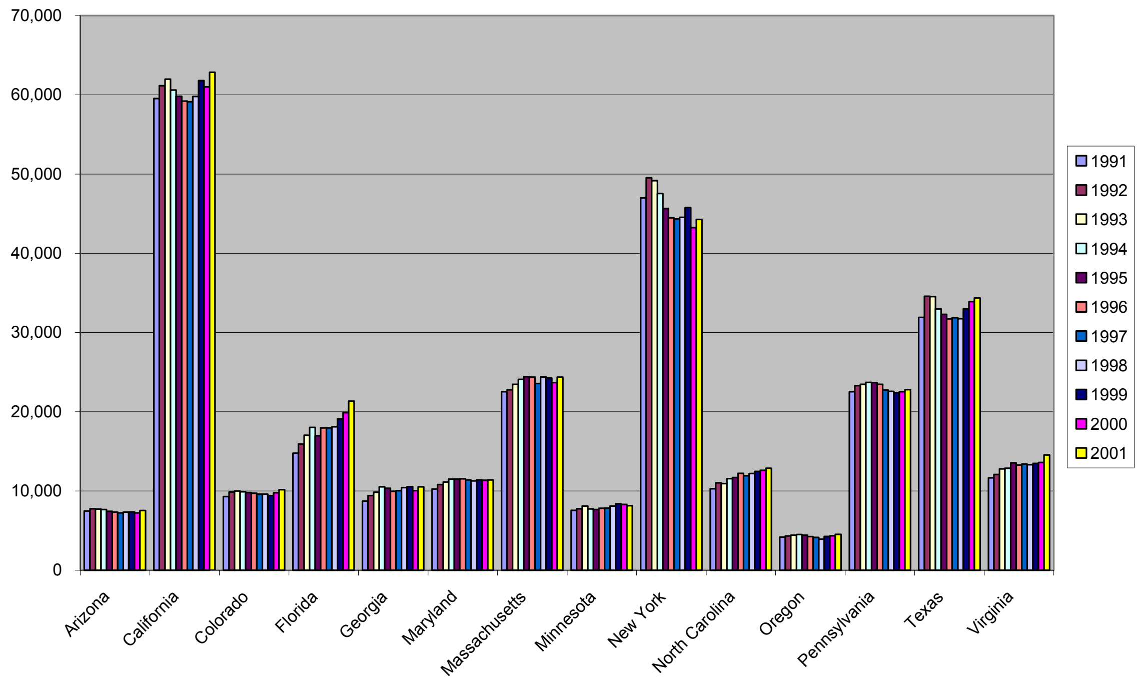


Science and Engineering Graduate Students, 1982-2001[96]

This indicator measured the number of science and engineering graduate students enrolled, at all levels, including health fields (excluding M.D.s). The number of science and engineering graduate students per capita is also calculated. Texas had a high total number of science and engineering graduate students, relative to the other states, though consistently fewer than California or New York. The total number of graduate students in Texas gradually climbed upwards from 1982-1993, and then leveled off.

[96] National Science Foundation/Division of Science Resources Statistics. Graduate Students and Postdoctorates in Science and Engineering (Washington, D.C.). Reports from 1972 to 1998 available online at http://www.nsf.gov/sbe/srs/gss98pub/start.htm. Per capita figures were derived by dividing the state total by the state population for the corresponding year. Population totals are from U.S. Department of Commerce, Bureau of the Census. Population Division. State Population Estimates: April 1-July 1, for 1980-2001.

Total Science and Engineering Graduate Students, 1991-2001

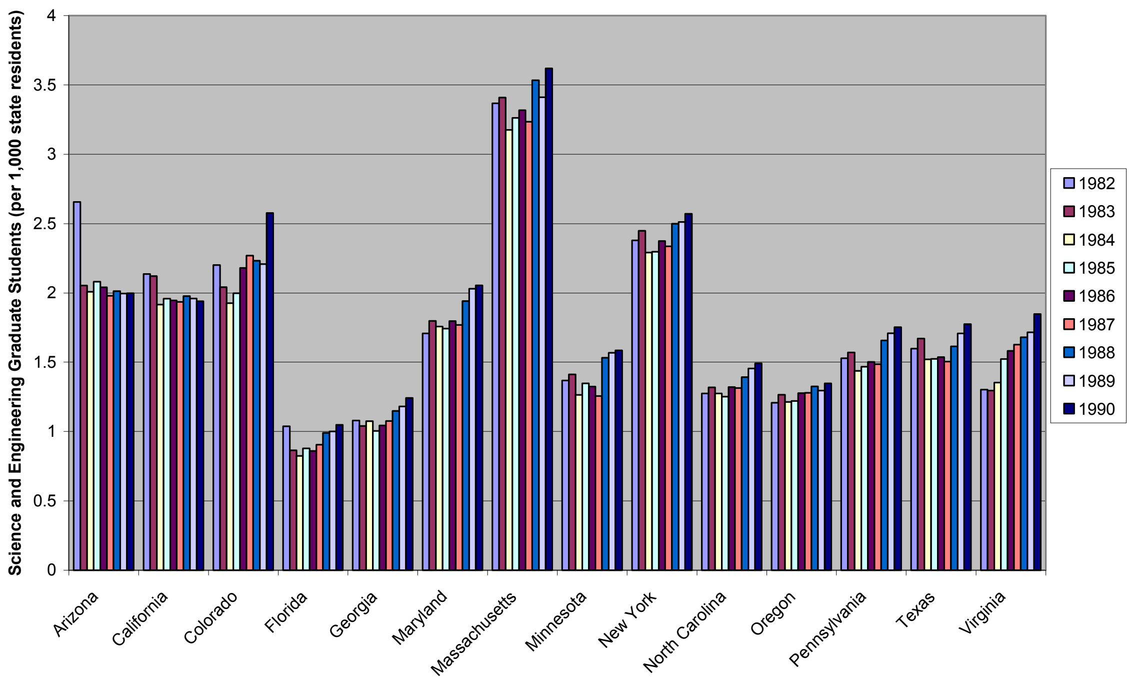


However, the number of *per capita* graduate students in Texas actually declined steadily between 1993 and 2001. Texas consistently ranked below many of the leader states in the number of per capita graduate students.

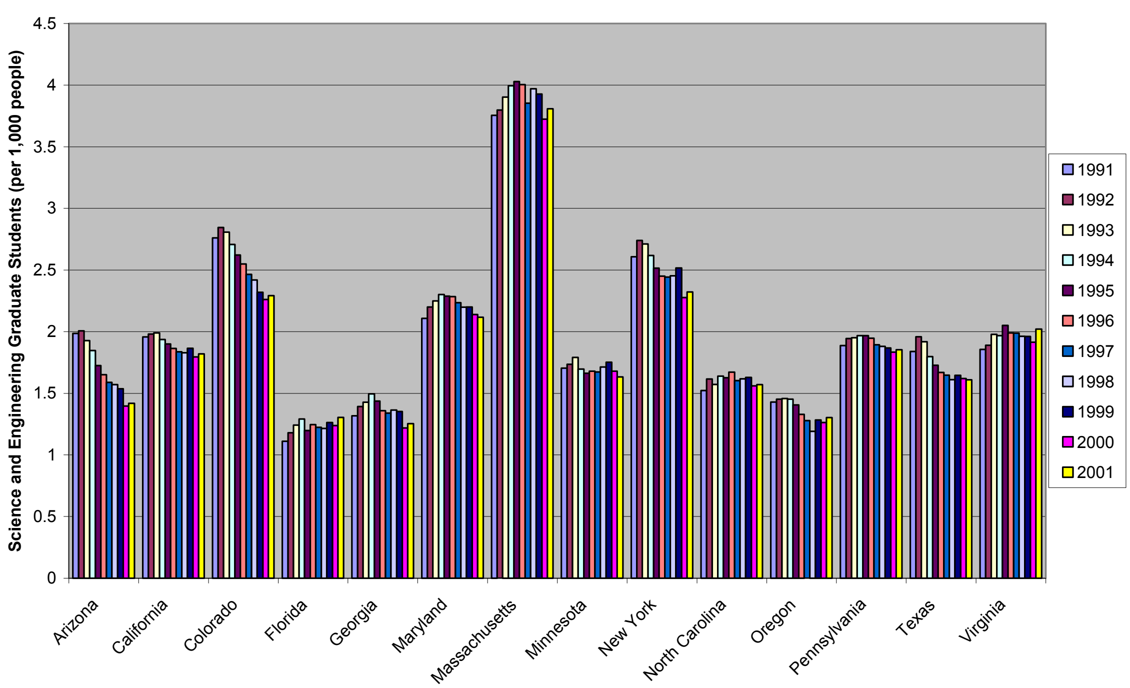
Per Capita Graduate Students: State Rankings

1982		1990		2001	
MA	3.37	MA	3.62	MA	3.81
AZ	2.65	CO	2.58	NY	2.32
NY	2.38	NY	2.57	CO	2.29
CO	2.20	MD	2.06	MD	2.12
CA	2.14	AZ	2.00	VA	2.02
VA	1.71	CA	1.94	PA	1.85
TX	**1.60**	VA	1.85	CA	1.82
PA	1.53	**TX**	**1.78**	MN	1.63
MN	1.37	PA	1.75	**TX**	**1.61**
VA	1.30	MN	1.59	NC	1.57
NC	1.27	NC	1.49	AZ	1.42
OR	1.21	OR	1.35	OR	1.26
GA	1.08	GA	1.24	GA	1.25
FL	1.04	FL	1.05	FL	1.24

Science and Engineering Graduate Students Per Capita, 1982-1990



Science and Engineering Students Per Capita, 1991-2001



FINDINGS AND CONCLUSIONS

Analysis of Texas workforce data suggests that Texas' science and engineering workforce has developed very slowly in the past ten to fifteen years. For some indicators, such as the number of science and engineering graduate students studying at Texas, Texas has actually declined in per capita terms. Comparisons with other states reveal that Texas still ranks far below leader states such as California, New York, Colorado, Minnesota, and Maryland, on many indicators. To join the ranks of the leader states, considerable progress must be made in Texas' workforce development. Science and workforce indicators alone do not prove whether or not the ATP/TDT program has fulfilled its goals of diversifying and strengthening the state's scientific and technological workforce. However, indicators can provide insight into the challenges faced by the state during the duration of the ATP program.

7.2 Research and Development in Texas

HIGHLIGHTS

- When benchmarked against 13 other states, in both point-in-time and across-time comparisons, Texas' ranking is generally unfavorable in research and development expenditures. Only in terms of patents does Texas rank higher than many of the peer states and higher than the national average.
- The university institutional benchmarks show a mixed result for three universities in very limited point-in-time comparisons.
- The institutional benchmark comparisons for the Texas health institutions show a very positive result. The proportion of federal R&D captured by major Texas health institutions has increased over the past 20 years. A similarly positive trend is found with the proportion of academic R&D garnered by the major Texas health institutions—the rate of improvement has been approximately 10 times faster than one would expect due to population growth alone.

BACKGROUND

The ATP program represents a small fraction of academic research and development expenditures within the State of Texas. In fiscal year 2002, total R&D expenditures were approximately $2.09 billion,[97] while ATP and TDT funding for that year was about $20 million, or roughly 1% of the total.

In this section, benchmarking data are provided across states at a particular point in time as well as across time. At the outset, data compare R&D across states, rather than

[97] See www.thecb.state.tx.us/reports/pdf/0599.pdf , table 3.

institutions. Then select institutional level data are provided for public universities and health-related institutions within Texas. Lastly, health-institution data over time are presented. Together, the graphs provide a context within which ATP research and development is conducted.

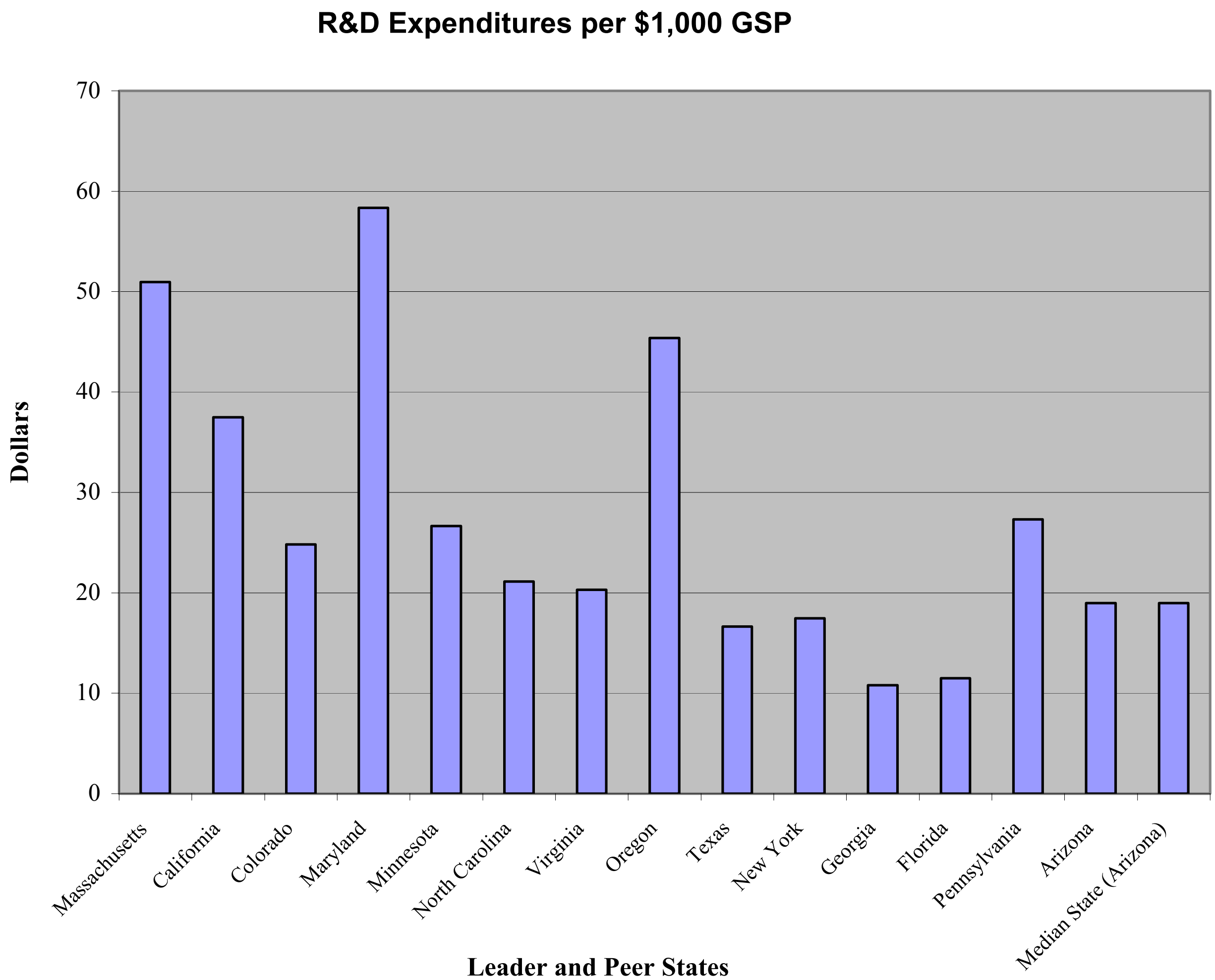
POINT-IN-TIME STATE RANKINGS

A set of comparisons of research and development expenditures in Texas was developed which is similar to that in the section above comparing the Texas science and technology workforce with workforces in other states. The states selected for comparison are Massachusetts, Oregon, California, New York, Colorado, Maryland, Georgia, Minnesota, North Carolina, Florida, Pennsylvania, Virginia, and Arizona. The selected states fall generally into two categories: 1) leader states (Massachusetts, California, Colorado, Maryland, Minnesota, North Carolina, Virginia, and Oregon) that have made efforts to build large science and technology bases; and 2) peer states (New York, Georgia, Florida, Pennsylvania, Arizona), often used for comparisons and benchmarking studies involving Texas.

To avoid differences in the sizes of states and states' absolute R&D expenditures, comparisons were made with normalized data. For instance in the first four tables, all R&D expenditure data were computed per $1000 of a state's gross state product (GSP).[98] The resulting values (i.e. the ratio of a state's R&D spending as a percentage of the state's GSP) for each state provide an indication of the relative R&D resources.

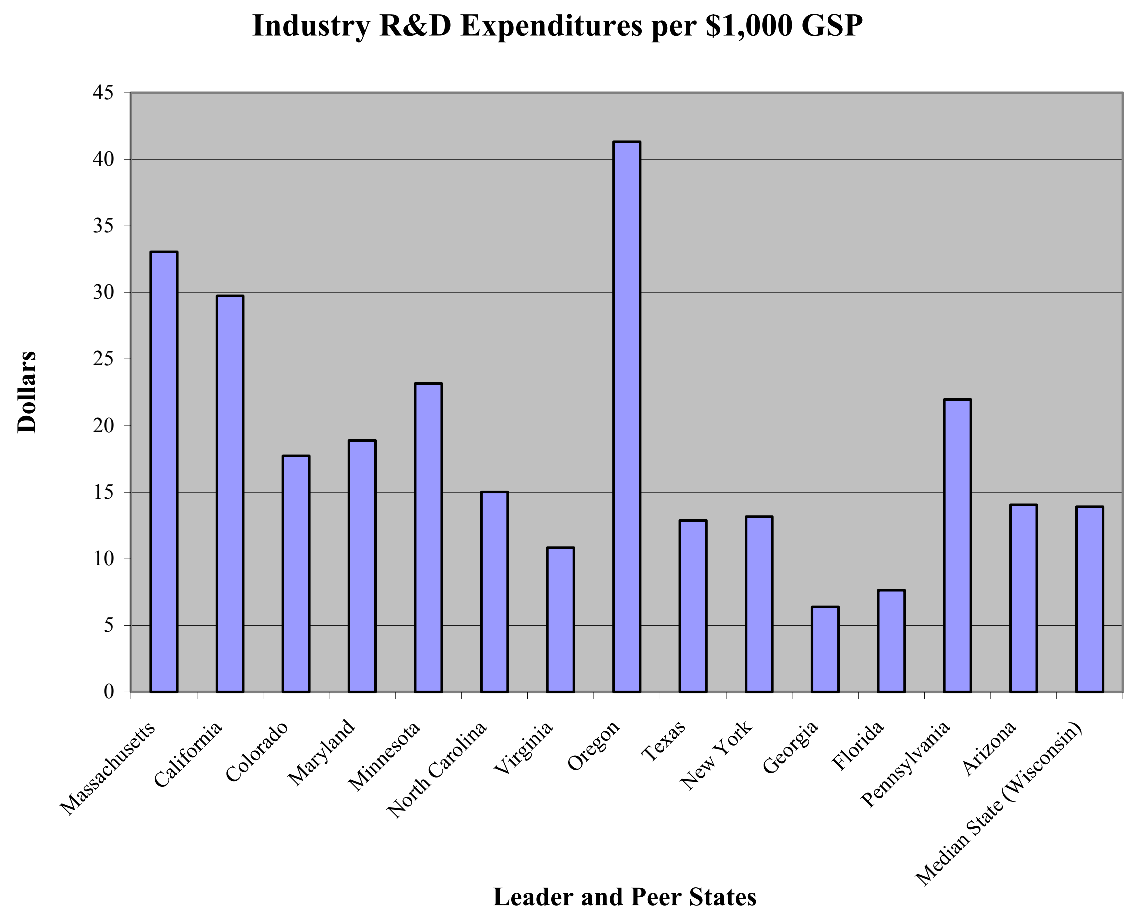
The first graph below shows the total R&D expenditure ratios in 2001 for the 14 states as well as the median state, which in this instance is Arizona, a peer group state. Maryland reported the highest ratio per $1000 GSP ($58.35) with Massachusetts ranking second ($50.95). Texas, at $16.65, ranked near the lower end of the spectrum: ranking 30th out of the 50 states. Georgia and Florida were the only two peer states with lower ratios than Texas.

[98] A gross state product is a measure of the total size of a state's economy and the state equivalent of the national Gross Domestic Product (GDP).



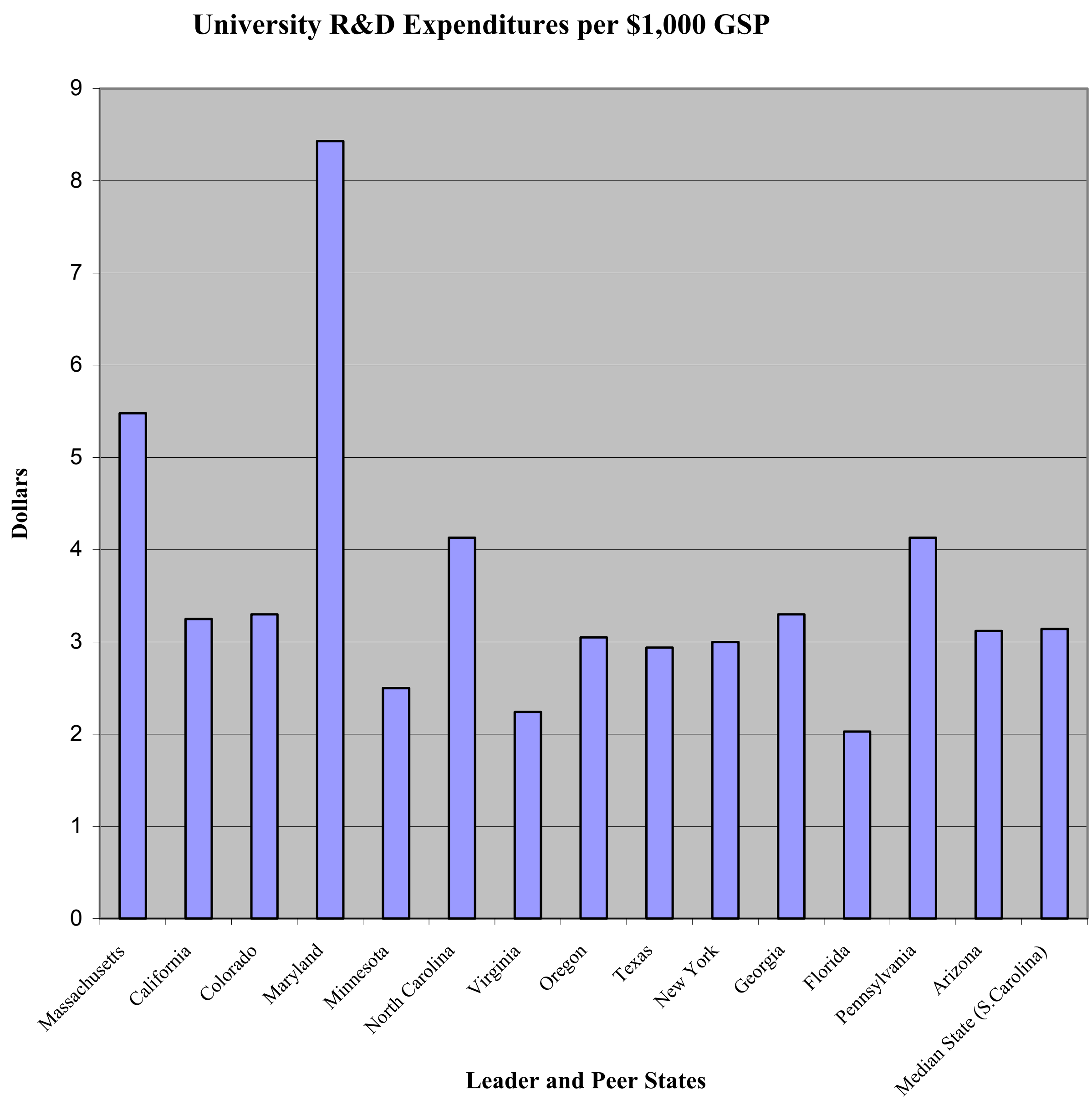
Sources: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition. Original sources for Expenditures for Total R&D Expenditures: National Science Foundation, Division of Science Resources Statistics; Gross State Product: U.S. Department of Commerce, Bureau of Economic Analysis.

The total R&D expenditures within a state are comprised of two components: (1) R&D spending by industry and (2) R&D spending by universities. The graph on industry R&D, which appears on the next page, shows that in 2001, Oregon had the highest industry R&D expenditures with Massachusetts second highest. As with total R&D expenditures, Texas again ranked below the median state, reporting only $12.88 industry R&D expenditure per $1000 GSP, and above only three peer states: Virginia, Georgia, and Florida.



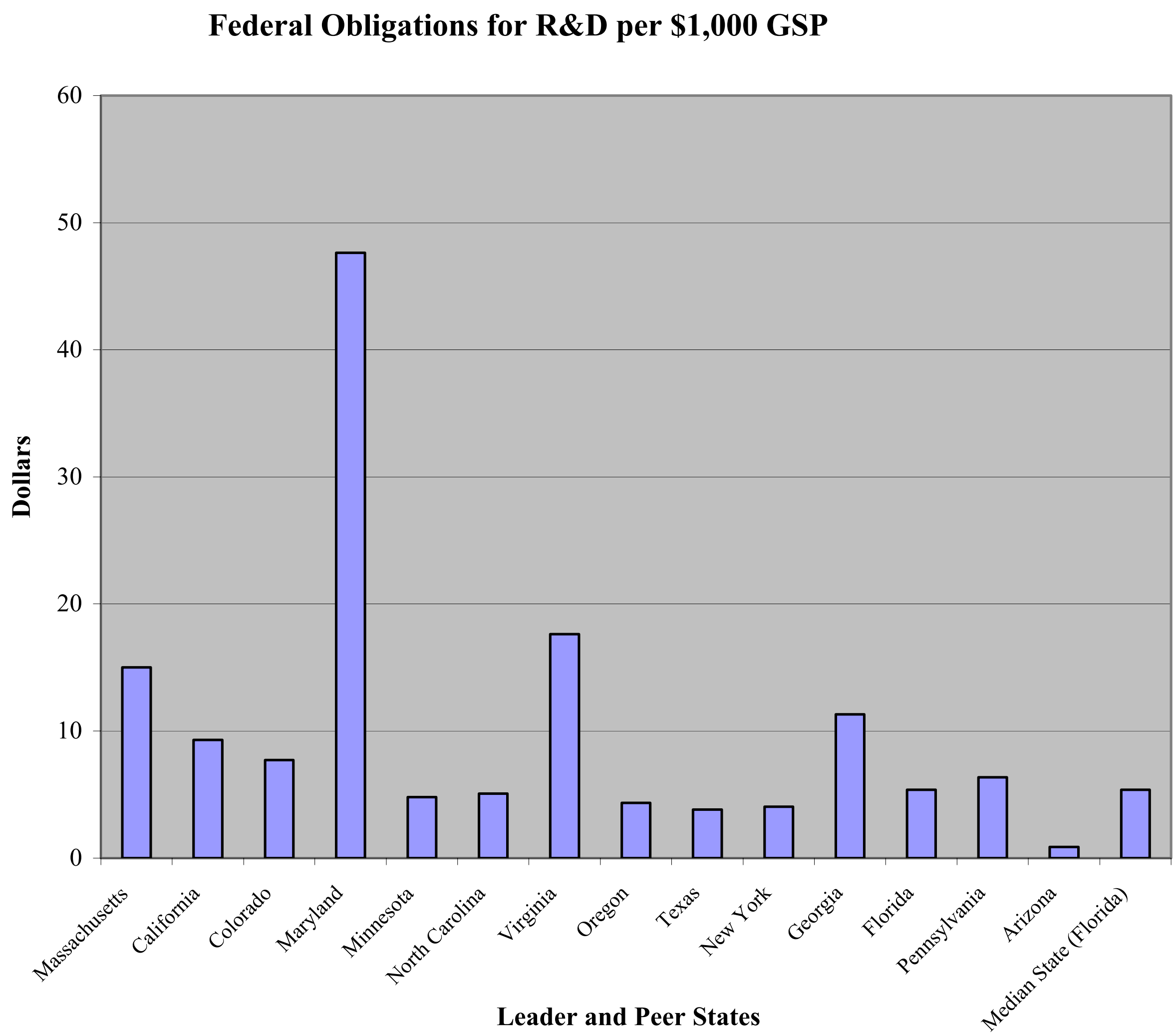
Sources: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition. Original sources for Expenditures for Total R&D Expenditures: National Science Foundation, Division of Science Resources Statistics; Gross State Product: U.S. Department of Commerce, Bureau of Economic Analysis.

For university R&D expenditures (next page), Maryland ranked first, reporting $8.43 per $1000 GSP followed by Massachusetts at $5.48 per $1000 GSP. Texas ranked 31st among all states, with $2.94 per $1000 GSP. In comparison to peer states, Texas' ratio exceeded only those of Minnesota, Virginia, and Florida.



Sources: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition. Original sources for Expenditures for Total R&D Expenditures: National Science Foundation, Division of Science Resources Statistics; Gross State Product: U.S. Department of Commerce, Bureau of Economic Analysis.

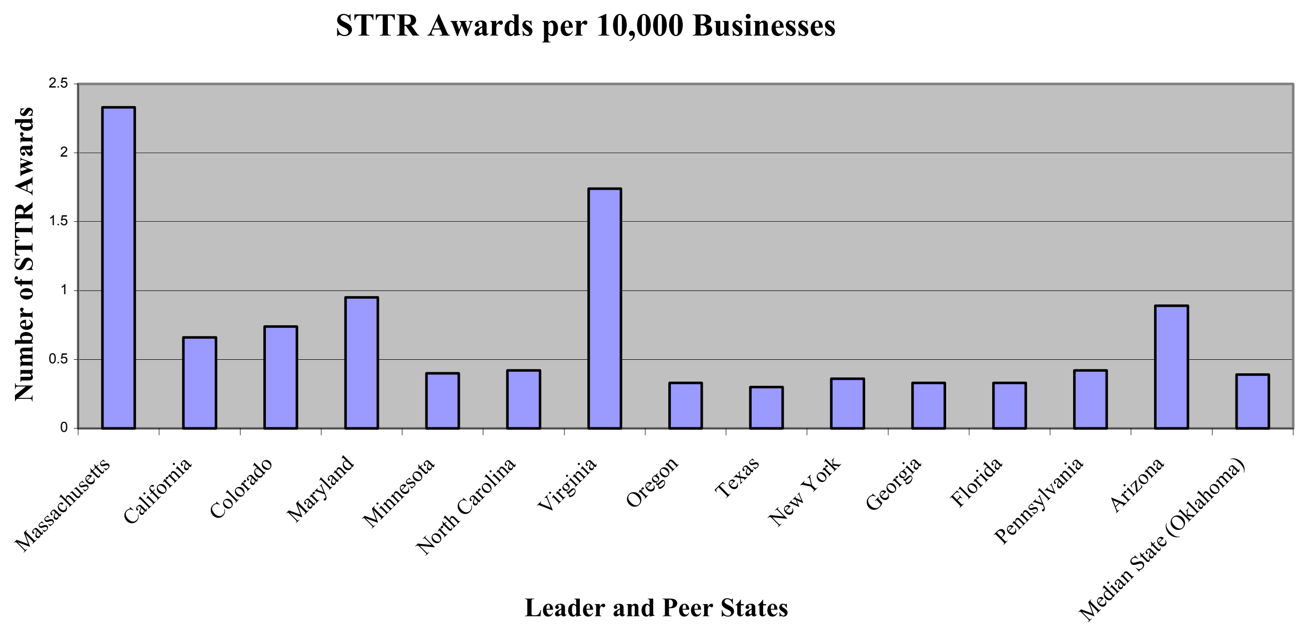
With respect to federal obligations only, Maryland ranked first in obtaining federal funding for R&D with $47.64 per $1000 GSP. Virginia and Massachusetts ranked 4th and 5th respectively. Texas again ranked below the median state and all but one of the peer states (Arizona), reporting only $3.83 in federal obligations for R&D per $1000 GSP in 2001.

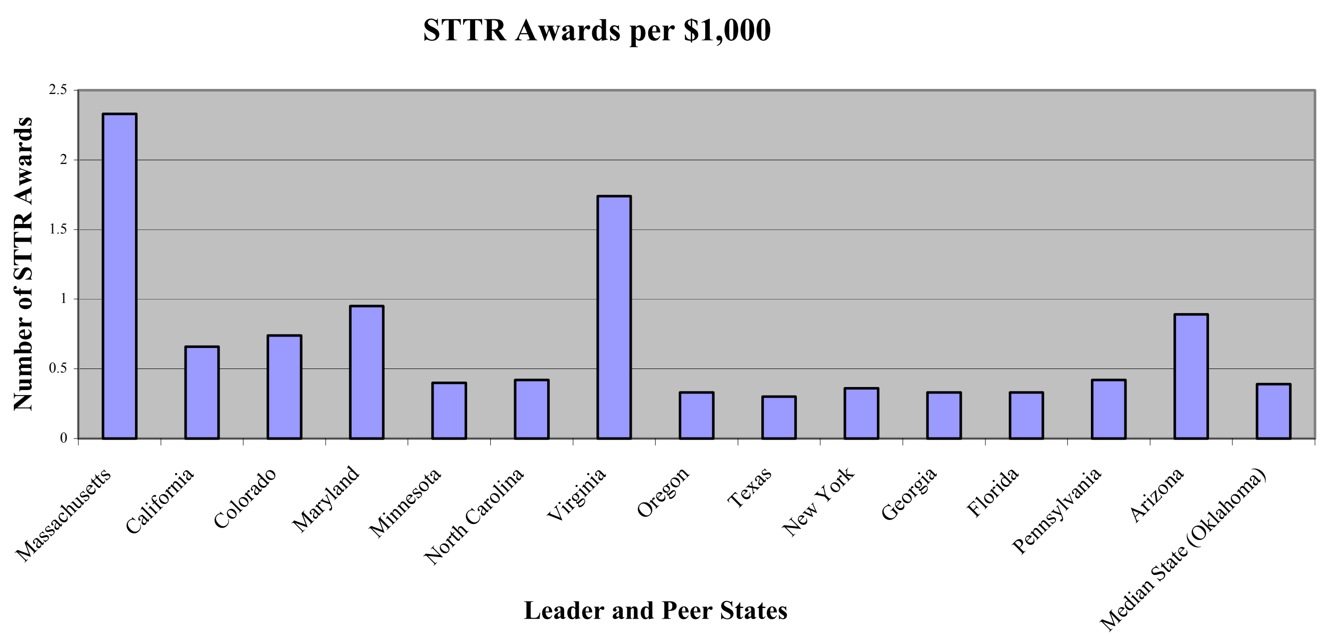


Sources: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition. Original sources for Expenditures for Total R&D Expenditures: National Science Foundation, Division of Science Resources Statistics; Gross State Product: U.S. Department of Commerce, Bureau of Economic Analysis.

Another indication of a state's R&D standing is its participation in the federal government's Small Business Technology Transfer Program (STTR). While SBIR is limited to small businesses, STTR requires applications from a lead small business in cooperation with a non-profit institution, often a university. Five major federal agencies (NSF, DOD, DOE, DHHS, and NASA) reserve a portion of their R&D funds for STTR awards.

Two graphs depicting information on STTR grants are shown below. In terms of the number of STTR awards per 10,000 businesses, Massachusetts ranked first with 2.33 STTR awards, followed by Virginia, with 1.74 STTR awards. Maryland and Arizona also reported high numbers of awards. Texas ranked 31st, below the median state of Oklahoma, with 0.3 STTR awards per 10,000 businesses.



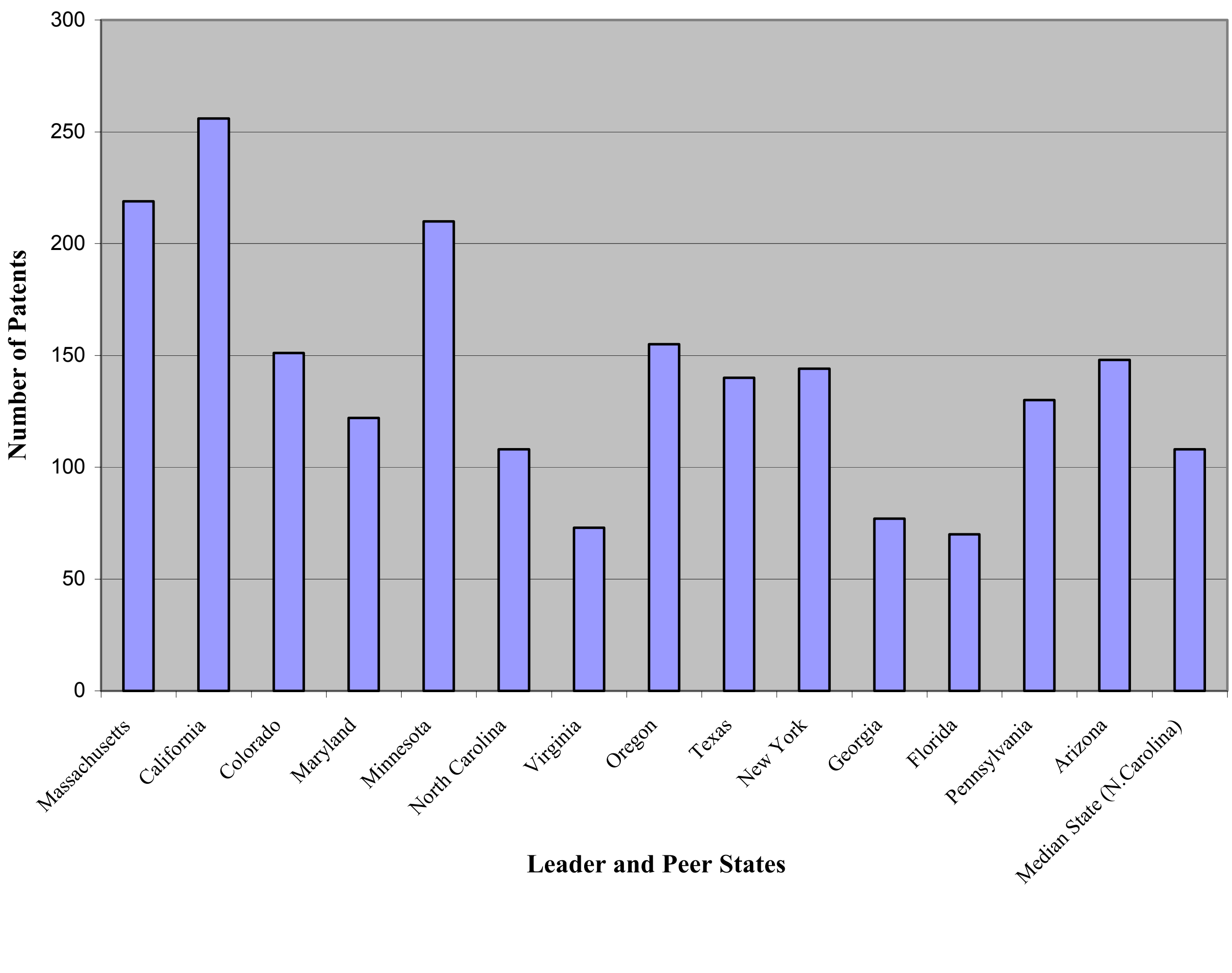


Sources for both graphs: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

As shown on the previous page, in terms of the number of STTR awards per $1,000 of Gross State Product, Massachusetts again ranked first among all states. Virginia, Maryland, and Arizona also ranked highly, while Texas ranked below the median state and lowest in the peer group.

One final measure of state R&D performance is number of patents issued. This indicator is a rough gauge of the intellectual property being created in a state, and a high ratio suggests that R&D is being pursued aggressively. In 2001, California ranked first in patents issued per 10,000 businesses. California reported 256 patents, followed by Massachusetts with 219 patents and Minnesota with 210 patents. Texas ranked 17th, above the median state of North Carolina, with 140 patents per 10,000 businesses, and higher than peer states Maryland, Georgia, Virginia, Florida, and Pennsylvania.

Patents Issued per 10,000 Businesses

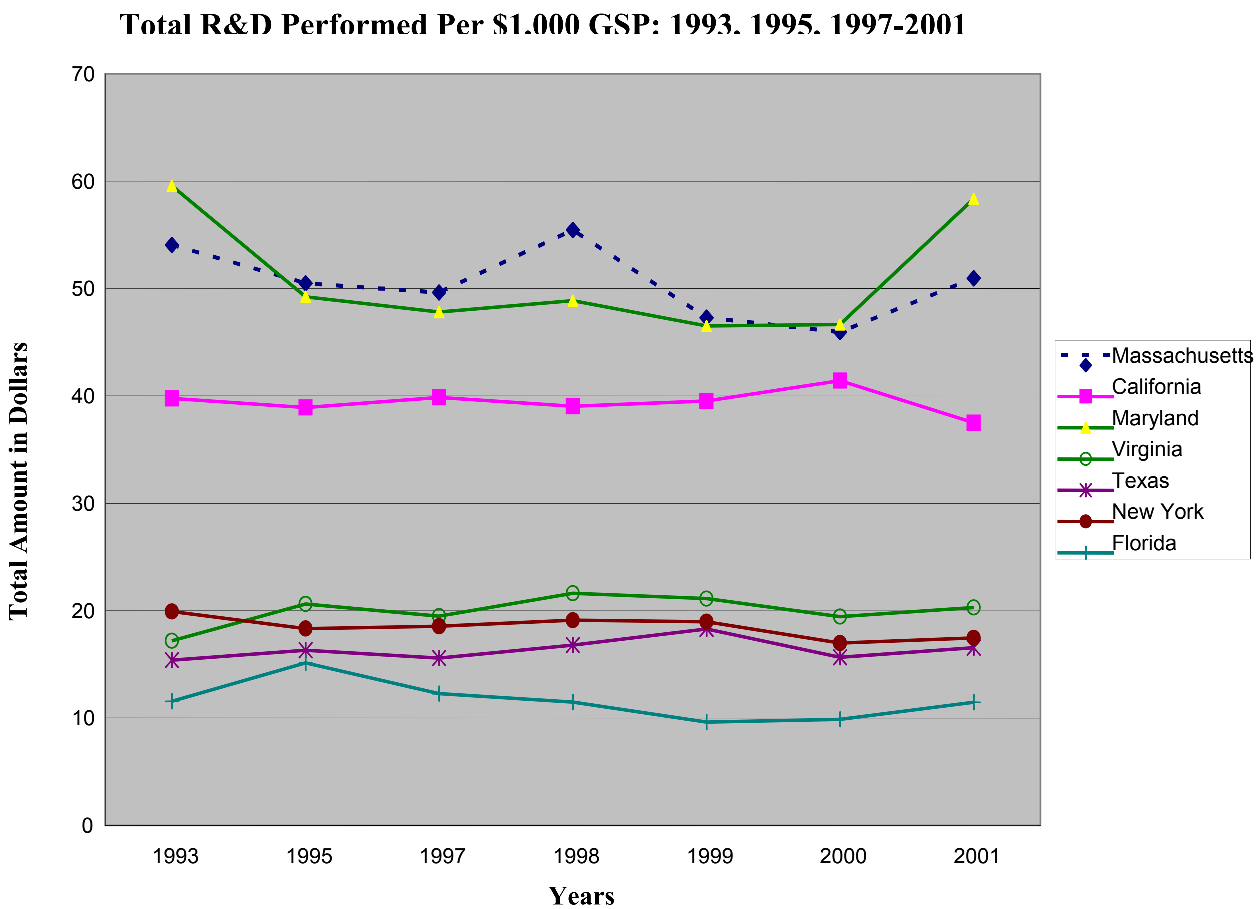


Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

ACROSS TIME STATE COMPARISONS

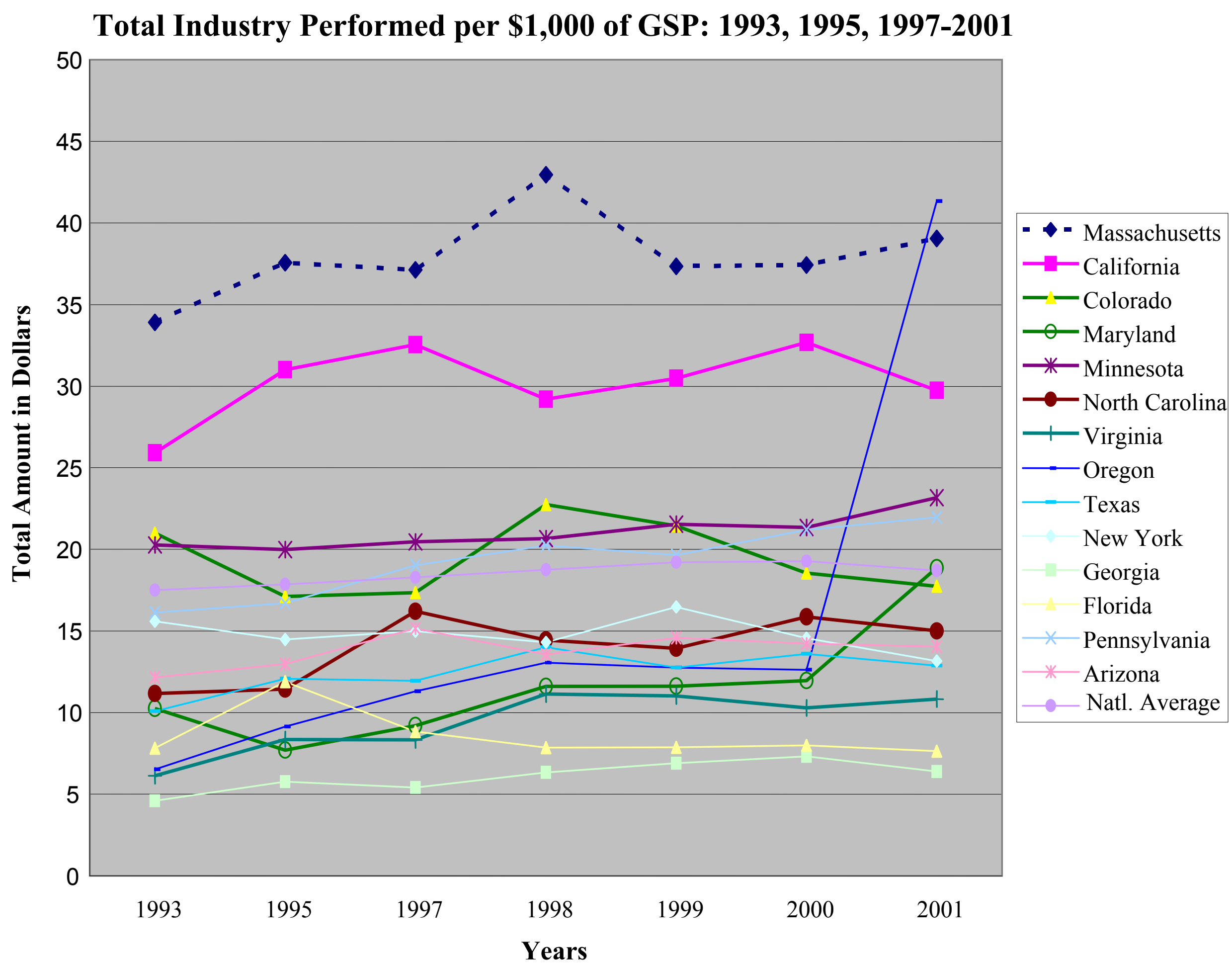
In the previous graphs, Texas had a relatively modest record compared to its peer states. The graphs below depict trend data for a subset of the leader and peer states.

For total R&D performed per $1,000 from 1993 through 2001, most states showed minimal change and reported similar patterns. Maryland, Massachusetts, and California had the highest proportion of total R&D performed in 1993 and 2001. Texas ranked sixth out of the seven states at both the beginning and the end of the period.



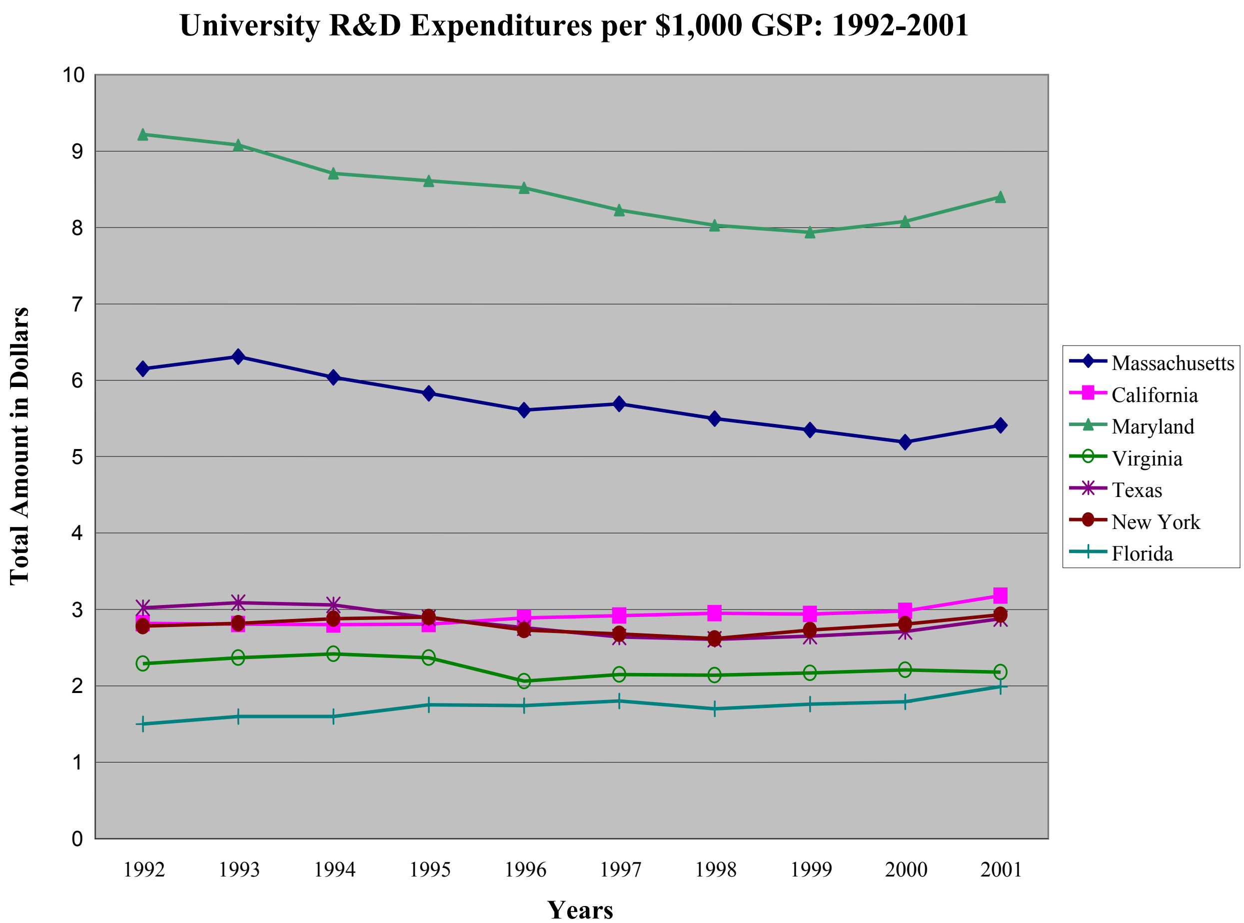
Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

Below, data are shown for industry R&D performed for 1993-2001. Oregon ranked highest in 2001. Otherwise, Massachusetts and California retained their first and second rankings throughout the time period. Texas ranked above Florida, Georgia, Virginia, and Oregon in 1993 and above only Florida, Georgia, and Virginia in 2001. Texas ranked below the national average every year. Minnesota, North Carolina, and Colorado gained ground in the rankings during the eight year period.



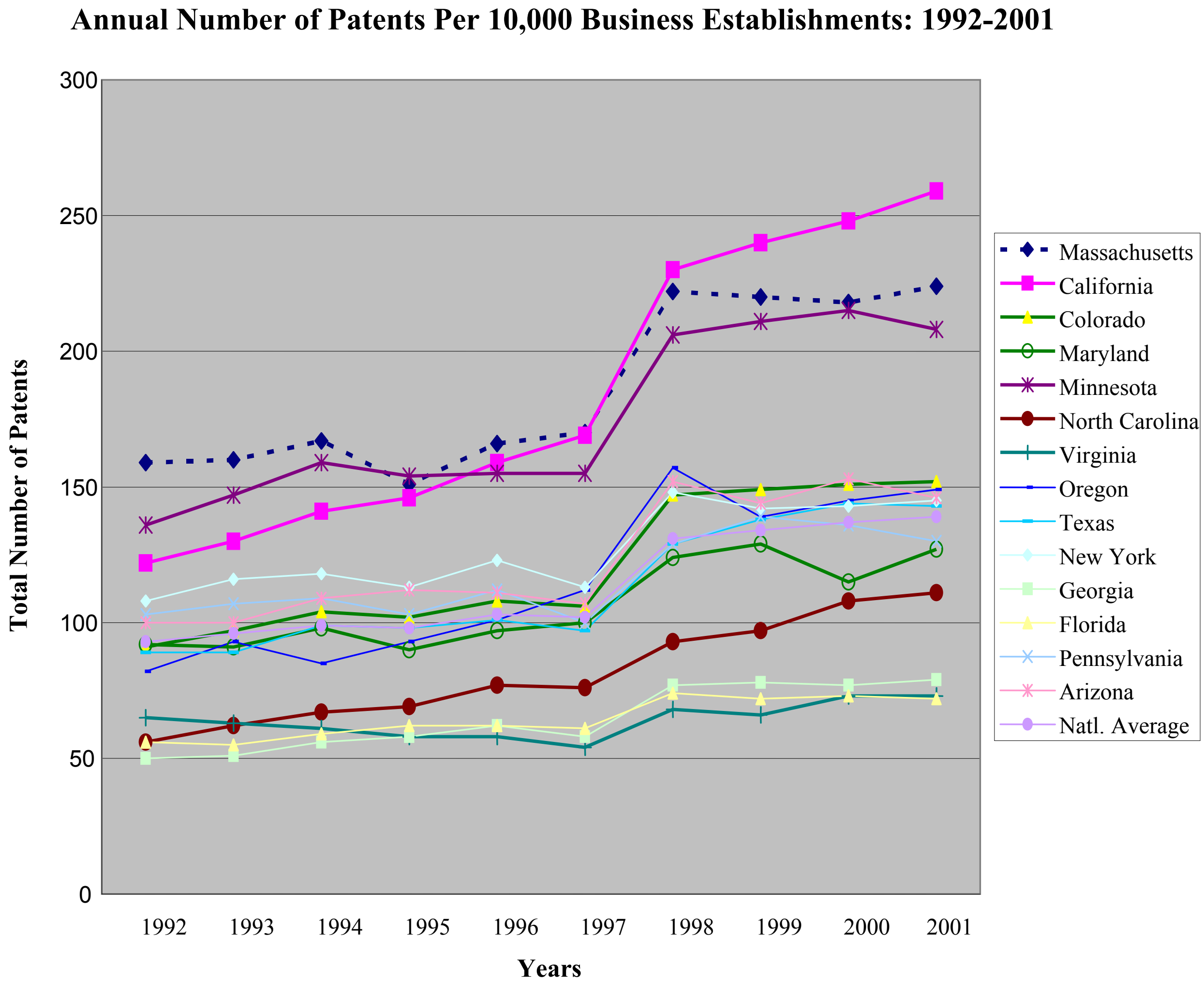
Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

For university R&D expenditures, below, the state rankings changed only marginally over the time period. Maryland, by far, ranked first among all states, with a ratio of nearly three times that of other states, except for Massachusetts. In this smaller group of peer states, Texas ranked above four states in 1992, but above only Virginia and Florida in 2001. Note that Maryland and Massachusetts ratios declined over the eight year period.



Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

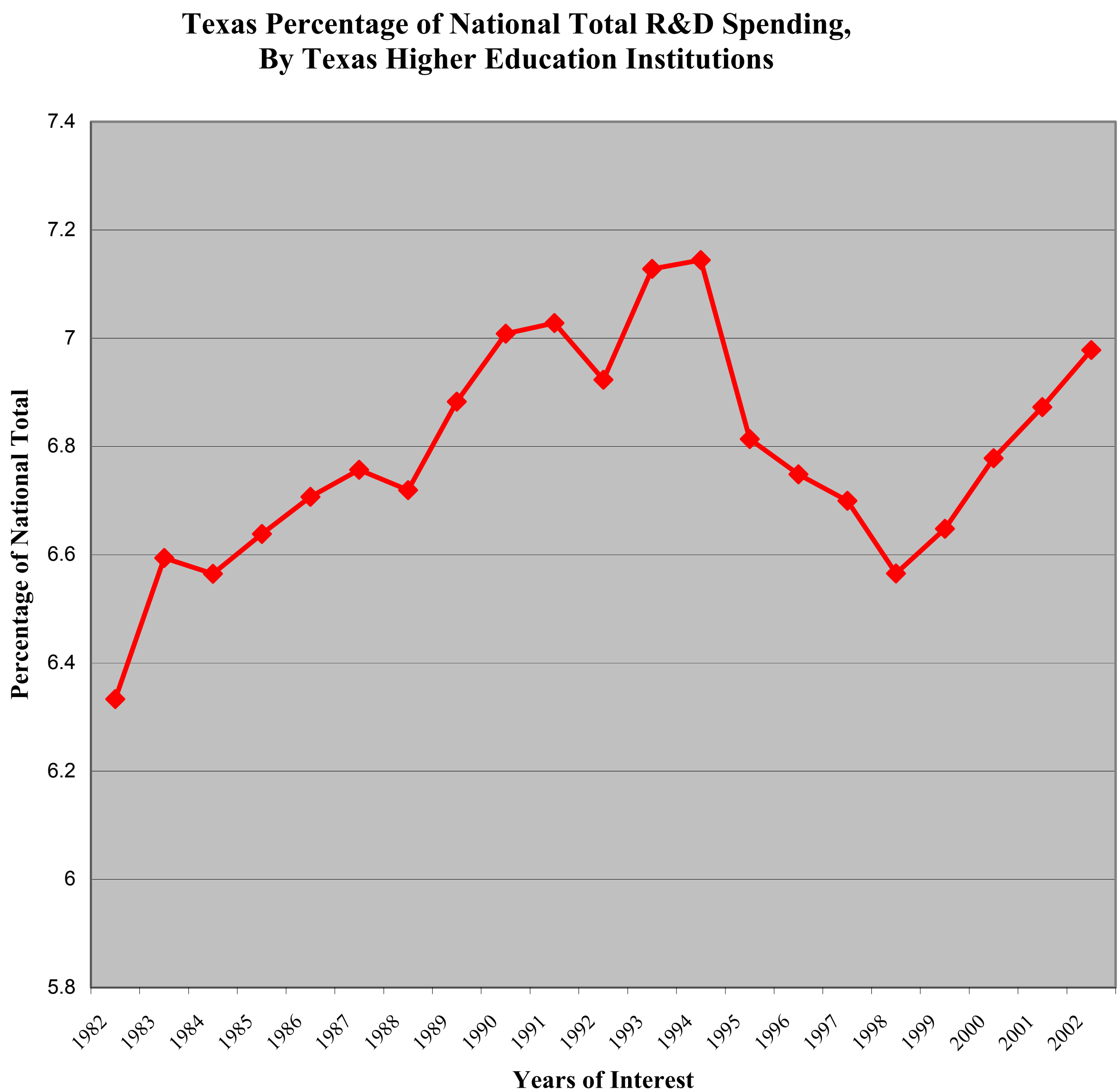
A final graph in this series depicts the trends in number of patents per 10,000 business establishments. Massachusetts, Minnesota, and California led all other states by a considerable margin. Texas was among a second group of states approaching the national average. A third group of peer states, comprised of Florida, Georgia, and Virginia had lower rates. All states of interest showed a marked increase in the patent rate over this ten year period.



Source: U.S. Department of Commerce, Technology Administration, State Science & Technology Indicators: Fourth Edition.

The graphs on the next two pages show a more positive trend for the state of Texas than the previous longitudinal graphs and the across-state, point-in-time comparisons. The first chart below chronicles Texas' proportion of national total R&D spending over the past twenty years. In 1982, Texas held approximately 6.3% of the nation's total, and peaked at 7.1% in 1994. In the most recent year for which data is available, Texas recorded 6.9% of the national total R&D spending. While this increase bodes well for the future, the rate is still less than one would expect with regard to population growth. Over these two decades, Texas' share of the total national R&D expenditure has increased about 10%, while the state's share of the nation's population has increased by about 14%.[99]

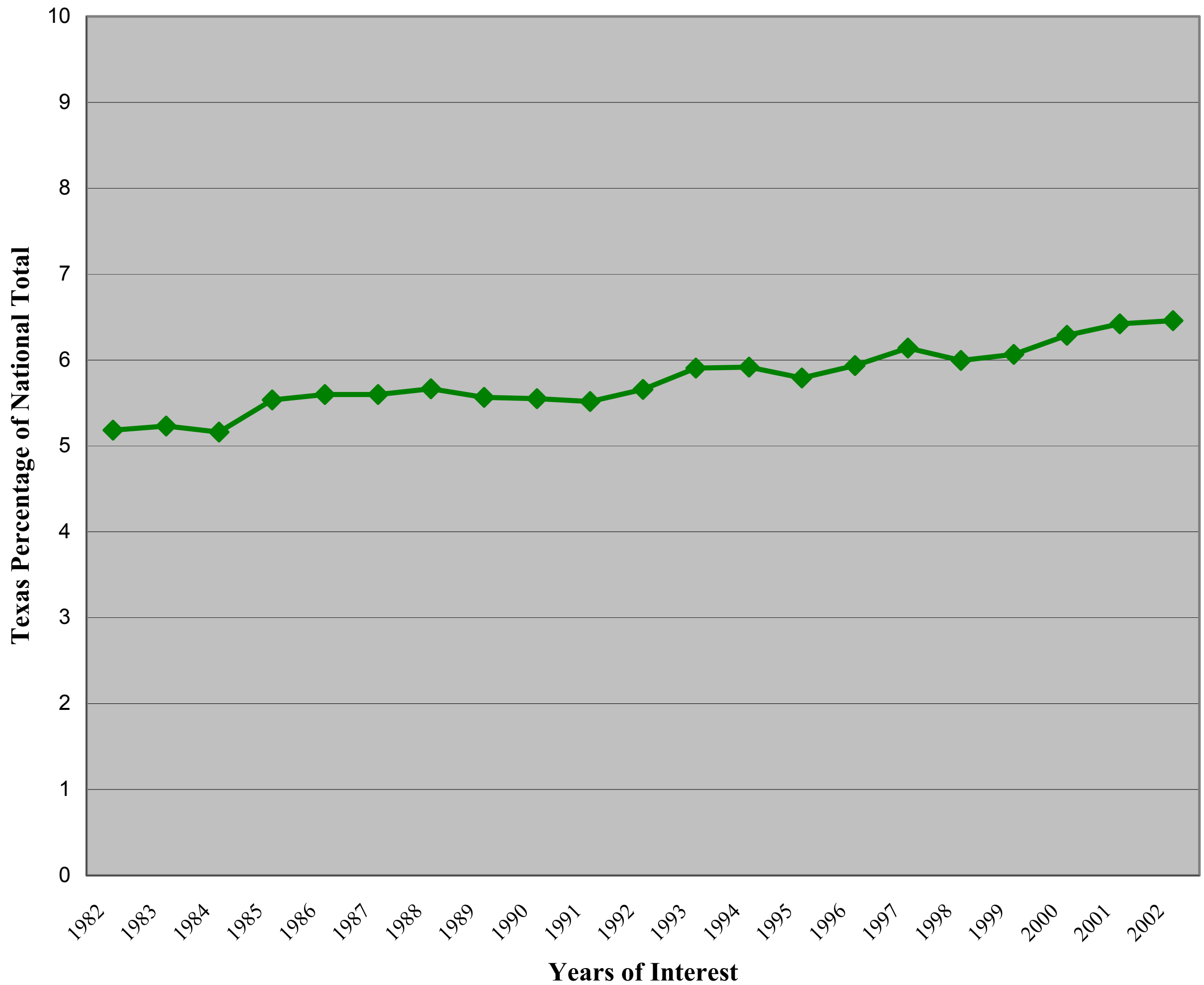
[99] In 1982, Texas comprised 6.62% of the US population. In 2002, that proportion had increased to 7.55%.



Sources: Calculated from National Science Foundation WebCASPAR Database. See http://caspar.nsf.gov
Population data obtained from: US Census Bureau, population estimates.

A different conclusion may be reached by examining Texas' proportion of federal R&D funding for the same time period. Over these twenty years, Texas gained some ground, moving from slightly above 5% of total federal R&D spending in 1982 to a high of 6.45% in 2002. This 29% increase surpassed the state's percentage of the nation's population which increased by 14%.

Texas Proportion of Federal R&D Funding,
By Texas Higher Education Institutions



Source: Calculated from National Science Foundation WebCASPAR Database. See <u>*http://caspar.nsf.gov*</u>
Population data obtained from: US Census Bureau, population estimates.

INSTITUTIONAL BENCHMARKS

To further explore current institutional commercialization of research and development, we developed several point-in-time comparisons for the fiscal year 2002. Data were extracted from the Association of University Technology Managers (AUTM) annual survey.[100] We selected three Texas institutions (Texas A&M University System, University of Texas at Austin, and Texas Tech University), and fifteen other universities throughout the country. Several, such as the University of California System, Stanford

[100] See AUTM Licensing Survey: FY 2002, Survey Summary, Attachments A-F.

University, Massachusetts Institute of Technology, Cornell, and the University of Wisconsin are reputed to be leaders in commercialization. We randomly selected an additional ten public universities as potentially comparable institutions.

Using raw data from AUTM, we developed a variety of benchmark measures to standardize the comparisons. The totals were computed on the basis of one year's

Name of Institution	**Total Sponsored Research Expenditures**
University of California System	$2,417,638,000
Massachusetts Inst. of Technology	$898,989,000
University of Wisconsin, Madison	$662,100,000
Stanford University	$573,416,214
University of Minnesota	$494,265,000
North Carolina State University	$478,613,713
University of Colorado	$470,400,000
Cornell Research Mo., Inc.	$465,700,000
Texas A&M University System	*$436,681,000*
Ohio State University	$361,119,508
Univ. of Texas, Austin	*$320,966,000*
Michigan State University	$289,787,000
Iowa State University	$212,100,000
Florida State University	$154,705,048
Texas Tech University	*$82,800,000*
Arizona State University	$77,120,773
Kansas State Univ. Research Fdn.	$71,333,972
Louisiana State Univ., Ag. Center	$52,825,977
Sample Institution Total	$8,520,561,205
National Totals	$31,695,704,942

Source: Computed from data in AUTM Licensing Survey: FY 2002, Survey Summary, Attachments A-F.

research expenditure data. While it is extraordinarily unlikely that such outcomes would be directly dependent on one year's research expenditures, as these outcomes will result from research over multiple years, the comparisons should prove nevertheless valid as most universities exhibit minimal variation in research expenditures from one year to the next. The above table shows the absolute research expenditures for the institutions in the sample for FY 2002. These amounts include all research, including projects involving basic science, social sciences, and the humanities. Some institutions report data on a system basis, while others provide data for each major university. This is a key distinction. In fact, both Texas A&M and Texas Tech include their health institutional data within their overall totals. The University of Texas at Austin data are only for that campus.[101]

Three different comparisons involving intellectual property are shown in the following table. For the expenditures per invention disclosure, the number of invention disclosures in 2002 is expressed as a ratio of the total research expenditure total for each institution. Therefore, for Texas Tech, there was one invention disclosure on average for every $1.335 million in research funds. (A lower number indicates that fewer dollars are required per each invention disclosure. This lower number is considered "better," which leads to a *higher* ranking in the table.) Texas Tech was second only to Arizona State on this measure. Both Texas A&M System and the University of Texas at Austin were below the national average.

On a related second measure, expenditures per U.S. patents filed, Arizona State also ranked first. Both Texas Tech and Texas A&M System ranked near the top of the scale, while the University of Texas at Austin was slightly below the national average of approximately one patent application per $2.9 million in research expenditures.

In terms of expenditures per U.S. patents issued, Texas Tech led all institutions in this sample for 2002: for every $4.6 million in research, the university received one patent. The national average was approximately one patent per $10.2 million in research expenditures. Both Texas A&M University System and the University of Texas at Austin were below the national average. Across all three measures, the leaders were Arizona State, Stanford, MIT, and Texas Tech.

[101] Because medical institutions, on average, have higher ratios of intellectual property and licenses per million dollars of research expenditures than universities, the Texas A&M System and Texas Tech System ratios in the following tables may be higher than for their primary campuses.

Expenditures Per Invention Disclosure		***Expenditures Per U.S. Patent Filed***		***Expenditures Per U.S. Patent Issued***	
Arizona State Univ.	$795,060	Arizona State Univ.	$714,081	*Texas Tech Univ.*	*$4,600,000*
Texas Tech Univ.	*$1,335,484*	Stanford Univ.	$1,769,803	Louisiana Agricultural	$5,282,598
Stanford Univ.	$1,786,343	MIT	$1,933,310	Stanford Univ.	$5,973,086
MIT	$1,857,415	Cornell Research	$2,438,220	MIT	$6,708,873
KSU Research Fdn.	$1,981,499	*Texas Tech Univ.*	*$2,587,500*	Michigan State Univ.	$6,739,233
Univ. of Minnesota	$2,094,343	*Texas A&M Univ.*	*$2,630,608*	Arizona State Univ.	$7,010,979
Iowa State Univ.	$2,121,000	Univ. of California	$2,734,885	KSU Research Fdn.	$7,133,397
Wisconsin Madison	$2,149,675	Univ. of Minnesota	$2,907,441	Iowa State Univ.	$7,313,793
Cornell Research	$2,186,385	**National Average**	**$2,981,161**	Wisconsin Madison	$7,610,345
Univ. of California	$2,484,726	Wisconsin Madison	$3,245,588	Univ. of California	$8,058,793
National Average	**$2,507,968**	Iowa State Univ.	$3,314,063	Cornell Research	$8,170,175
Louisiana Agricultural	$2,515,523	*Univ. of Texas, Austin*	*$3,343,396*	**National Average**	**$10,194,823**
NC State Univ.	$2,545,818	NC State Univ.	$3,418,669	Florida State Univ.	$10,313,670
Texas A&M Univ.	*$2,911,207*	Florida State Univ.	$4,550,148	*Texas A&M Univ.*	*$11,491,605*
Ohio State Univ	$3,140,170	Michigan State Univ.	$4,829,783	Univ. of Minnesota	$11,494,535
Michigan State Univ.	$3,533,988	Louisiana Agricultural	$5,282,598	NC State Univ.	$11,673,505
Univ. of Texas, Austin	*$3,867,060*	KSU Research Fdn.	$5,487,229	*Univ. of Texas, Austin*	*$15,284,095*
Univ. of Colorado	$3,887,603	Univ. of Colorado	$7,972,881	Ohio State Univ	$18,055,975
Florida State Univ.	$9,100,297	Ohio State Univ	$10,943,015	Univ. of Colorado	$27,670,588

Source: Computed from data in AUTM Licensing Survey: FY 2002, Survey Summary, Attachments A-F.

Health Nat. Average:	$2,084,933	Health Nat. Average:	$2,109,129	Health Nat. Average:	$8,608,579

The table on the next page shows a second set of comparisons focusing on licenses. For the first measure, the national average was one executed license for each $8.48 million in research expenditures in 2002. Iowa State ranked first with one license for each $739,000 in research funds, while Ohio State required more than $24 million for each executed license. Texas A&M System was slightly above the national average while the University of Texas at Austin and Texas Tech were slightly below the national average.

A second related measure shows the resource requirements on average for each license yielding income. (These are lower than the previous measure because licenses executed in <u>any</u> prior year are included, provided that they yield income to the university.) Again, Iowa State ranked first. Texas A&M System was fourth on this measure, while Texas Tech and the University of Texas at Austin were next to last and last, respectively.

The third measure shows the relationship between licensing and royalty income to the level of current research expenditures. Florida State ranked first, and received approximately one dollar in licensing income for every three it expended on research in 2002. The national average was one dollar in licensing income for every $32 of research expenditures. Texas A&M System, the University of Texas at Austin, and Texas Tech all ranked lower than the national average, suggesting that licensing income from past agreements has been lower than for other universities, given their levels of research.

Iowa State, Stanford, the University of Minnesota, and the University of Wisconsin, Madison were the only institutions that ranked above the national average on all three measures. Ohio State and Colorado were consistently low.

R&D Expenditures Per License Executed		***R&D Expenditures Per License Yielding Income***		***R&D Expenditures Per Dollar of License Income Received***	
Iowa State Univ.	$739,024	Iowa State Univ.	$509,856	Florida State Univ.	$3
Wisconsin Madison	$4,244,231	Stanford Univ.	$1,489,393	Michigan State Univ.	$10
Stanford Univ.	$5,409,587	KSU Research Fdn.	$1,981,499	Stanford Univ.	$11
Cornell Research	$5,679,268	*Texas A&M Univ.*	*$1,993,977*	Univ. of Minnesota	$19
Univ. of Minnesota	$6,961,479	MIT	$2,384,586	Iowa State Univ.	$20
MIT	$7,368,762	Cornell Research	$2,388,205	Wisconsin Madison	$21
Texas A&M Univ.	*$7,661,070*	Univ. of Minnesota	$2,471,325	Univ. of California	$29
National Average	**$8,477,054**	Univ. of California	$2,888,456	**National Average**	**$32**
NC State Univ.	$8,702,068	Wisconsin Madison	$3,261,576	MIT	$34
Louisiana Agricultural	$8,804,330	**National Average**	**$3,733,299**	Louisiana Agricultural	$36
Univ. of Texas, Austin	*$9,170,457*	Arizona State Univ.	$3,856,039	Arizona State Univ.	$44
Texas Tech Univ.	*$10,350,000*	Louisiana Agricultural	$4,063,537	*Texas A&M Univ.*	*$68*
Univ. of California	$10,890,261	Michigan State Univ.	$4,673,984	*Univ. of Texas, Austin*	*$82*
Arizona State Univ.	$11,017,253	NC State Univ.	$6,136,073	KSU Research Fdn.	$128
Michigan State Univ.	$13,172,136	Ohio State Univ	$8,807,793	NC State Univ.	$129
Florida State Univ.	$17,189,450	Florida State Univ.	$9,669,066	Cornell Research	$162
Univ. of Colorado	$18,092,308	Univ. of Colorado	$10,939,535	Univ. of Colorado	$224
KSU Research Fdn.	$23,777,991	*Texas Tech Univ.*	*$11,828,571*	*Texas Tech Univ.*	*$398*
Ohio State Univ	$24,074,634	*Univ. of Texas, Austin*	*$11,887,630*	Ohio State Univ	$436

*All Years for Licenses/2002 for Expenditures

Source: Computed from data in AUTM Licensing Survey: FY 2002, Survey Summary, Attachments A-F.

Health Nat. Average:	$6,439,488	Health Nat. Average:	$2,310,212	Health Nat. Average:	$13

The final measure shows the research expenditures on average for each start-up company rooted in university research. For all universities in 2002, the average was one company for every $87 million in research expenditures. This was based on a total of 364 start-up companies and $31.7 billion in research expenditures nationwide. As can be seen, Arizona State ranked first, MIT second, and Texas Tech third. The University of Texas at Austin ranked slightly above of the national average, and the Texas A&M System ranked below the national average.[102]

Name of Institution	**Expenditures Per Start-Up Company**
Arizona State Univ.	$25,706,924
Massachusetts Inst. of Technology	$39,086,478
Texas Tech Univ.	*$41,400,000*
Stanford Univ.	$44,108,940
Ohio State Univ.	$45,139,939
Florida State Univ.	$77,352,524
Univ. of Texas, Austin	*$80,241,500*
Univ. of Minnesota	$82,377,500
National Average	**$87,076,112**
North Carolina State Univ.	$95,722,743
Univ. of California System	$105,114,696
Iowa State Univ.	$106,050,000
Texas A&M Univ. System	*$109,170,250*
Cornell Research Mo., Inc.	$116,425,000
Univ. of Colorado	$156,800,000
Univ. of Wisconsin Madison	$165,525,000

Source: Computed from data in AUTM Licensing Survey: FY 2002, Survey Summary, Attachments A-F.

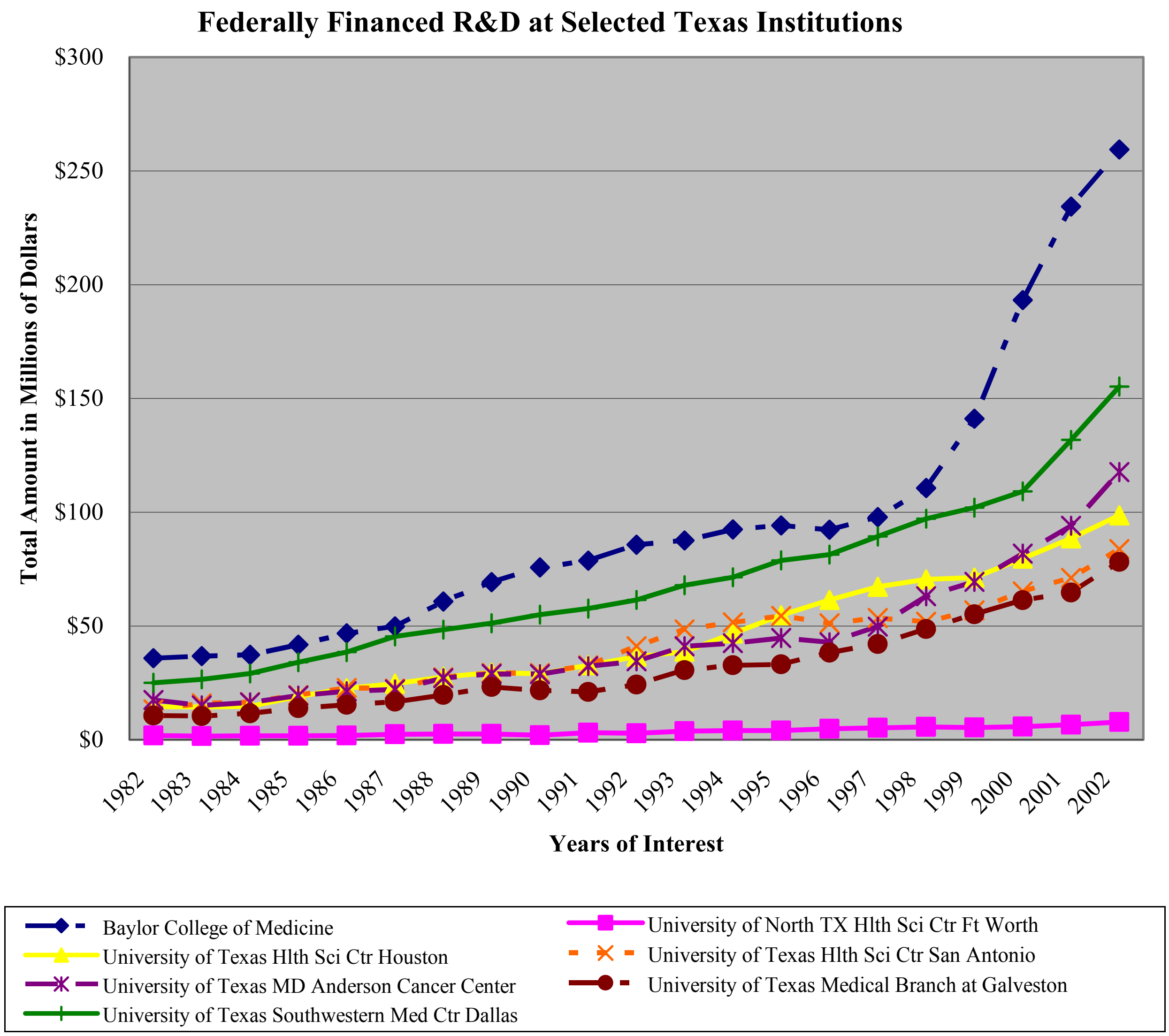
HEALTH-RELATED INSTITUTIONS

A more detailed examination was then made of select Texas health institutions.[103]

The graph below shows federally financed R&D, in absolute dollar amounts, at the major Texas institutions over the last twenty years. Baylor College of Medicine has consistently

[102] Texas A&M System and the University of Texas at Austin both reported four start-up companies in 2002, and Texas Tech reported two start-up companies.
[103] Only one of the major Texas medical institutions (MD Anderson) reported data to AUTM for 2002. Because of this, there is no equivalent review to that previously conducted for universities.

secured the greatest amount of federal R&D funding over this period, with a dramatic increase occurring in the latter years. The University of Texas Southwestern Medical Center and MD Anderson are second and third in absolute funding levels.



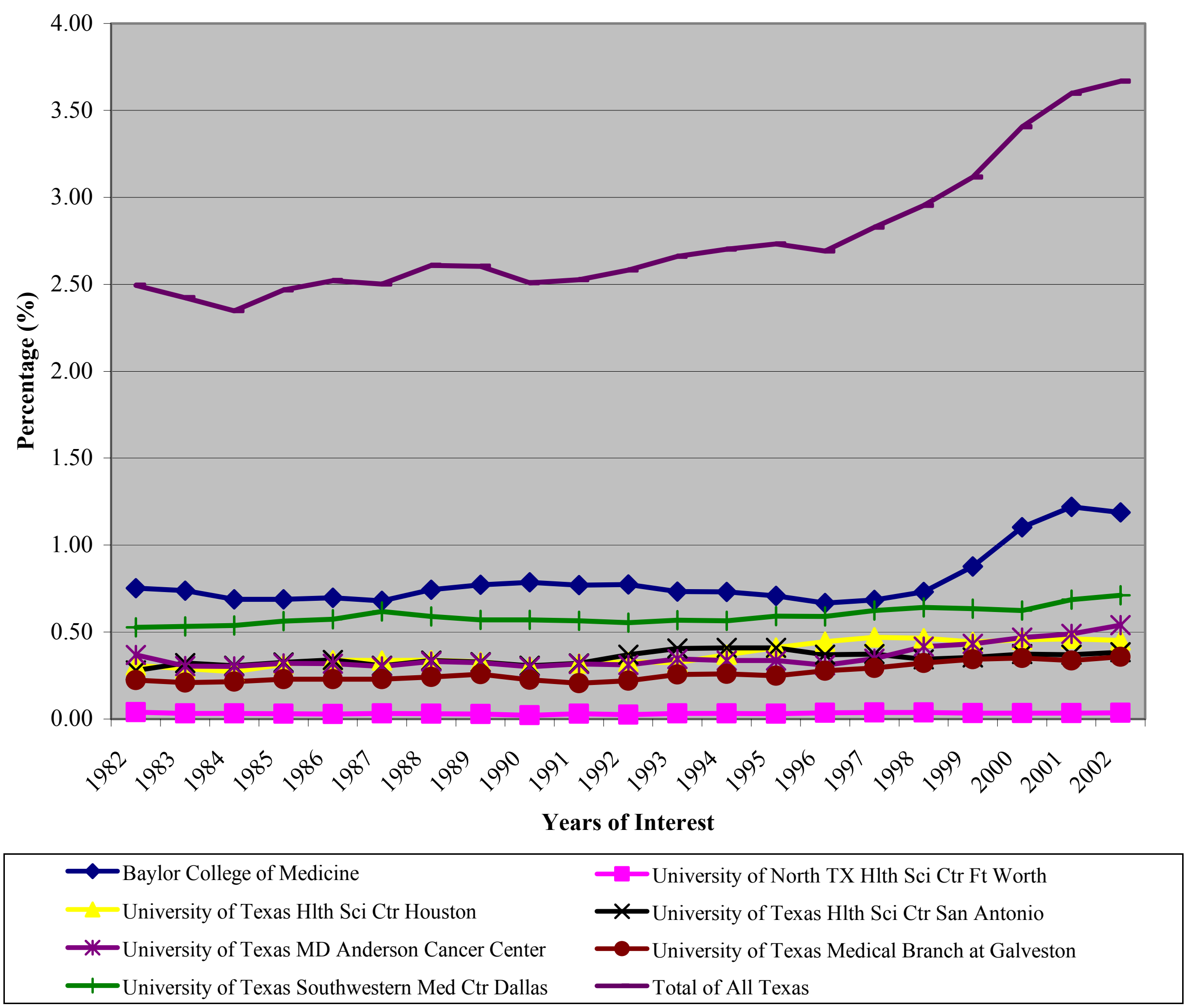
Source: Calculated from National Science Foundation WebCASPAR Database. See http://caspar.nsf.gov

The second chart, shown below, illustrates the *proportion* of federally-financed R&D at select Texas medical institutions from 1982 to 2002. Baylor College of Medicine recently surpassed 1% of federal R&D funding.[104] The second most successful Texas medical institution, the University of Texas Southwestern Medical Center, received around 0.5% of total federal R&D funding. In the aggregate, Texas' medical institutions show a marked increase in over the last twenty years. In 1982, Texas medical institutions

[104] This is total federal R&D funding, not only federal health funding.

totaled 2.5% of all federal R&D, whereas by 2002, Texas reported 3.68% of all federally financed R&D, an increase of approximately 47%. On a per capita basis, Texas' share of the national population increased during the 20 years by only 14%.

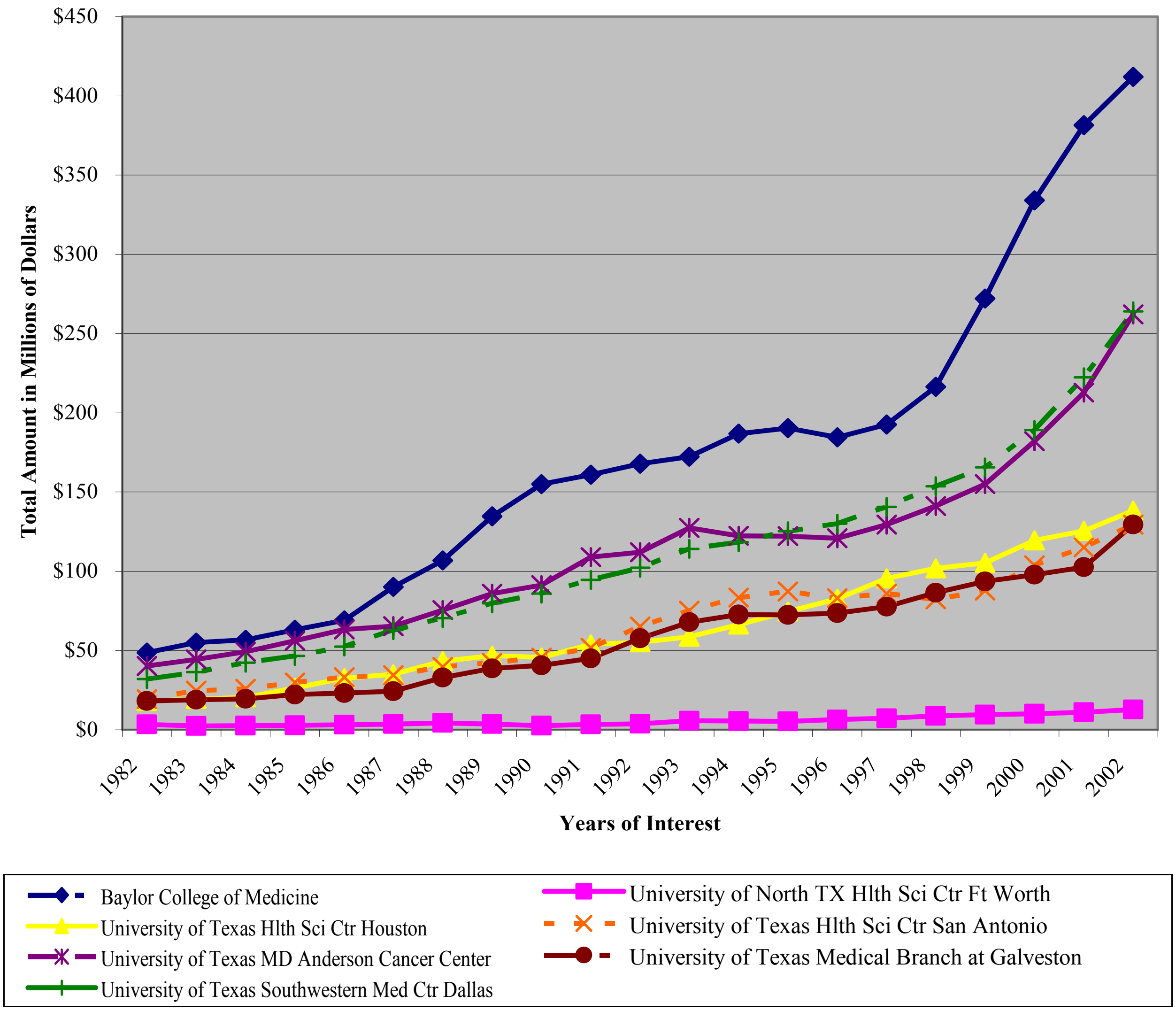
Percentage of Federally Financed R&D at Selected Texas Institutions



Source: Calculated from National Science Foundation WebCASPAR Database. See http://caspar.nsf.gov/

Research and development funding from all sources, not just the federal government, is shown below for the 20-year period. In 2002, Baylor College of Medicine had expenditures in excess of $400 million, followed by UT-Southwestern and MD Anderson with more than $250 million each. Funding at each of the three institutions increased markedly over the last five years of the time period. In the case of Baylor, expenditures nearly doubled.

Total Academic R&D Expenditures

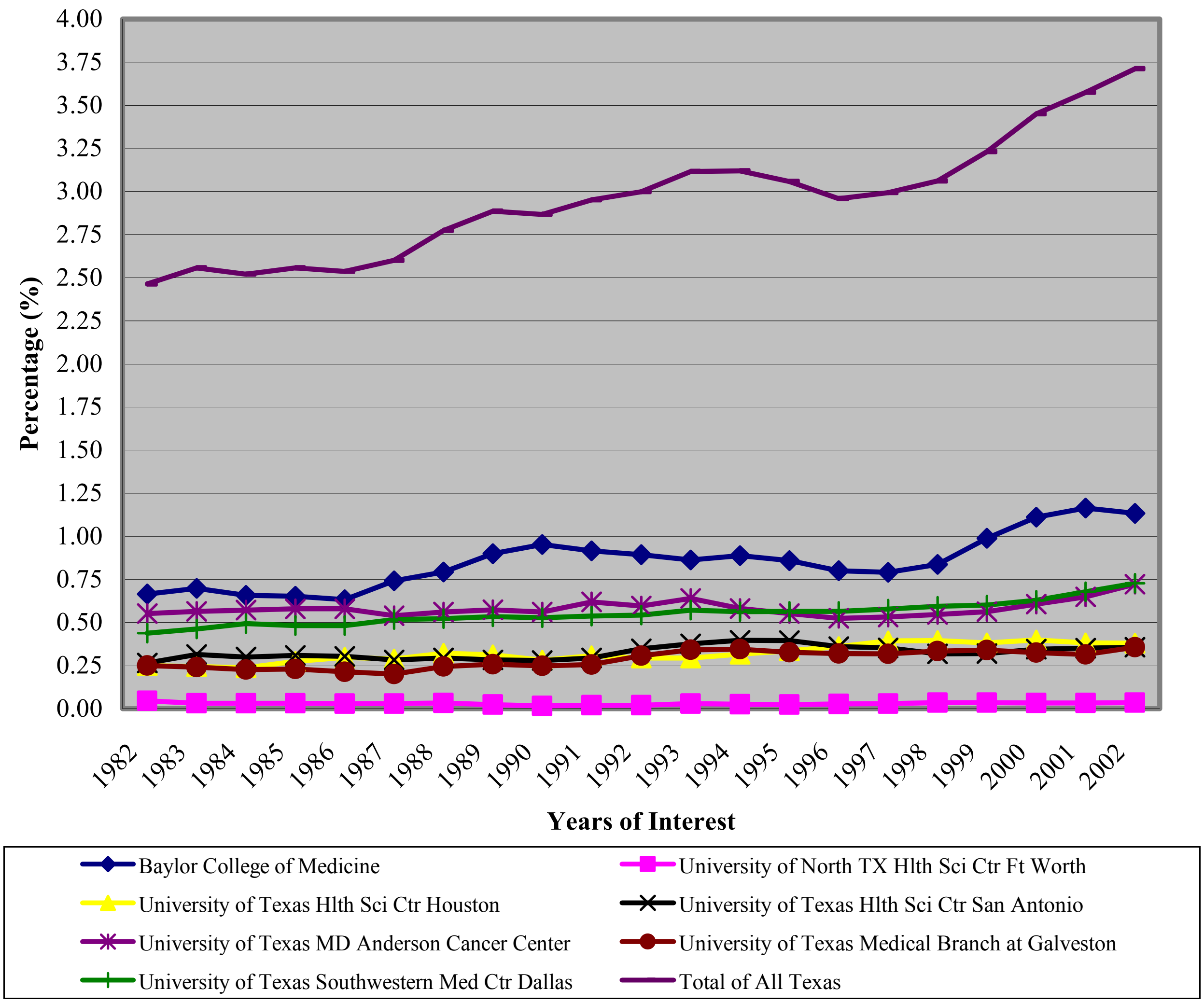


Source: Calculated from National Science Foundation WebCASPAR Database. See http://caspar.nsf.gov

The final chart presented below shows the proportion of expenditures at select Texas medical institutions from 1982 to 2002 and indicates a pattern similar to that of federally-financed R&D presented previously. Baylor College of Medicine's R&D expenditures, which surpassed 1% of federal R&D, also have surpassed 1% of total national R&D by academic institutions. The University of Texas Southwestern Medical Center and MD Anderson Cancer Center each now comprises nearly 0.75% of total national R&D expenditures at academic institutions.

Texas' medical institutions, as a group, show a strong increase in R&D expenditures over the last twenty years. In 1982, Texas medical institutions totaled 2.5% of all R&D expenditures by academic institutions in the United States; by year 2002, that proportion had increased to nearly 3.75%. Texas health institutions have increased their share of the total national R&D expenditures by 150%, while the population share has increased by about one-tenth (14%) that rate.

Percentage of Academic R&D Expenditures at Selected Texas Institutions



Source: Calculated from National Science Foundation WebCASPAR Database. See http://caspar.nsf.gov

OBSERVATIONS AND SUMMARY ON RESEARCH AND DEVELOPMENT

The prior R&D comparisons provide a context for the ATP program. In general, Texas compared unfavorably to other states. With the point-in-time comparisons, Texas ranked lower than most peer states on five measures, as well as ranking below the national average on five measures. Only in terms of patents did Texas rank higher than many of the peer states and higher than the national average.

The pattern was mixed in the six across-time comparisons. Texas ranked moderately well on two measures: patents and proportion of total R&D nationally throughout the time period and improved on one measure, proportion of federal R&D funding. On industry R&D expenditures as a proportion of GSP and total R&D expenditures as percentage of GSP, however, it ranked low throughout the time period and on the remaining measure (university R&D expenditures as a proportion of GSP), the ranking declined.

The university institutional benchmarks showed a mixed result for the three universities in the point-in-time comparisons. For the intellectual property measures (invention disclosures, patents filed, patents issued) about half the time the Texas universities ranked above the national benchmark. On two measures, Texas Tech ranked very highly, and UT-Austin ranked quite low. On the licensing measures, the three Texas universities generally ranked below the national average. On these, Texas Tech ranked quite low on two measures, as did UT-Austin on one measure. For start-ups, two of the three universities ranked above the national average, and Texas Tech ranked quite high.

The institutional benchmark comparisons for the Texas health institutions show a very positive result. The proportion of federal R&D captured by major Texas health institutions has increased over the past 20 years. The Baylor College of Medicine, UT-Southwestern, MD Anderson, and the UT Health Science Center in Houston had strong performances. A similarly positive trend was found with the proportion of academic R&D garnered by the major Texas health institutions. Not only has the combined proportion improved considerably, the rate of improvement was approximately 10 times faster than one would expect due to population growth alone. The Baylor College of Medicine, UT-Southwestern, and MD Anderson improved their share of R&D over this time period, and the increase by the Baylor College of Medicine was quite impressive.

7.3 Comparative Performance Metrics for ATP/TDT Research & Development Projects

HIGHLIGHTS

Based on 1,854 ATP/TDT projects, on average:

- 1 project in 3 will yield a patent application.
- 1 project in 3 will lead to some type of commercialization.
- 1 project in 5 will lead to an issued patent.
- 1 project in 6 will lead to a license.
- 1 project in 22 will result in new company formation.
- Excluding in-kind matching, each project will receive follow-on research funds of nearly three times the ATP grant.
- Each project will provide paid positions to five graduate and two undergraduate students.

- Compared to other reasonably similar programs, the Texas ATP demonstrated no substantial deficiencies on any metric. However, program comparisons must be considered quite cautiously due to differences in program objectives, award size, and structure.
- In comparison to the commercialization outcomes of U.S. and Canadian university and health institutions in general, Texas ATP ranked very highly.

BENCHMARKING PROCESS

ATP outcomes have been benchmarked against a number of different programs. An extensive search was conducted to identify similar state and federal programs that fund applied university research and development oriented toward commercialization. No equivalent programs were found. Some state governments fund applied R&D but the programs generally provide funding directly to companies or to companies engaged in collaborative projects with university researchers.[105] Examples of state programs were found that provide limited support to university PIs for specific purposes such as establishing new institutes or developing prototypes. Other states direct resources at downstream or commercialization activities such as incubators and financial support for new products and newly formed companies within the state. Other types of organizations also were examined for program analogues. For instance, universities participate in consortiums with grant programs for faculty. However, after close review, the research team determined that no program found was equivalent to ATP in scope, number, and focus of awards. Searches for non-U.S. programs, particularly in Canada, Australia, and Europe, also identified no analogues.

Ultimately, a limited number of organizations and programs, none of which is exactly comparable to ATP, were identified for the benchmark study, including

- AUTM 2002 Data for U.S. Universities, U.S. Hospitals, and Canadian Universities.
- A subset of 9 US federal laboratories, with more extensive data for Oak Ridge National Lab, Lawrence Berkeley National Lab, and Lawrence Livermore National Lab.
- Georgia Research Alliance.
- Federal Advanced Technology Program.
- Oklahoma Applied Research Program (OARS).

Consequently, inferences between Texas ATP and any other specific organization or program should be very carefully and cautiously drawn. When taken in their entirety, however, benchmarked programs provide additional insight into ATP program

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[105] There are many examples: the Maine Technology Institute with three active grant award programs was recently evaluated: Seed Grants; Development Awards; and Cluster Enhancement Awards. See: http://www.mainetechnology.org

performance and results.

EXPLANATORY COMMENTS ON TABLE DATA

Comparative data are displayed in Table 1. The data for U.S. universities, U.S. Hospitals and Research Institutes, and Canadian Institutions are drawn from the Association of University Technology Managers 2002 Survey. The Texas ATP data are derived from responses to the electronic survey of principal investigators conducted under the auspices of this assessment during spring 2004. In order to standardize the comparisons, all data were normalized on the basis of $1 billion in research expenditures.
The difference between the ATP results and the results for U.S. universities, U.S. hospitals and research institutes, and Canadian institutions is striking. For all metrics except licenses with industry, ATP shows rates that are higher by at least a factor of five. For the license metric, the ATP rate is approximately three times higher than that of U.S. universities and more than twice that for U.S. hospitals and research institutes. For start-up companies, the ATP rate is 10 times greater, at a minimum.

The subset of nine U.S. federal laboratories funded primarily by the Department of Energy and the Department of Defense consists of: Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Engineering & Environmental Lab, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, and Oak Ridge National Laboratory. The consolidated data of commercialization metrics for the federal labs are slightly less than those of U.S. universities and significantly less than the ATP program.

Detailed data are separately displayed for three major federal laboratories: Oak Ridge, Lawrence Berkeley, and Lawrence Livermore. With most metrics, results for the three labs are lower than for the other institutions except for U.S. patents issued. Oak Ridge performs similarly to U.S. and Canadian institutions in the absolute number of new companies formed. On all metrics, the three federal labs record results that are substantially less than the Texas ATP program.

Limited data are available from the federal Advanced Technology Program, the Oklahoma Applied Research Program (OARS), and the Georgia Research Alliance (GRA).[106] The leverage ratio on funding from both OARS and GRA indicate a ratio of 6:1, while the Texas ATP ratio is less than 3:1. The leverage ratio from OARS and GRA includes required matching funds of 1:1. If the OARS matching funds are excluded, the ratio is reduced to 5:1. Significantly, OARS data includes venture capital that universities, businesses, and researchers have received, whereas the Texas ATP follow-on funds consist only of grants.

Due to fundamental differences in program features owing primarily to award size and

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[106] Descriptions of these programs are provided at the end of Table I and should be read carefully to prevent misinterpretation of the data.

normalization, true comparisons between the federal ATP and Texas ATP are very difficult, as demonstrated by the following four examples. The federal ATP rate of filed patents for each project is approximately 1.5 per project, while the Texas ATP rate is 0.34.[107] Given that federal ATP awards on average are a minimum of 10 times larger than Texas ATP awards, the rate of patents filed on $1 billion of research expenditures from the federal ATP is 516 while from Texas ATP the rate is 1,989. Consequently, the Texas ATP value (normalized per $1 billion in research expenditures) is approximately four times larger than the federal ATP.

On the basis of the first fifty completed federal ATP projects, four in ten culminated with an issued patent as compared to two in ten Texas ATP projects. However, due to the large difference between the two programs' average award size, the Texas ATP rate normalized per $1 billion research expenditures is larger: 962 on inflation-adjusted basis compared to 271 for the federal ATP.

In whole numbers, about the same proportion of federal and state ATP projects yield licenses--approximately one in seven federal ATP projects are licensed compared to one in six Texas ATP projects. After the data are normalized on the basis of $1 billion in research expenditures, the rate from the federal ATP is 51 compared to an inflation-adjusted rate of 767 from Texas ATP. As for license income, the rate from the federal ATP was $52 million per $1 billion in R&D expenditures while the Texas ATP rate was $120 million.

A comparison of federal and Texas ATP demonstrates unambiguously positive commercialization results. To date, the percentage of federal ATP projects currently in commercialization is very high. Of federal ATP funded projects, more than half of the companies of single applicant projects reported at least some revenue or experienced reduced costs of production. Of joint venture projects, that figure rose to almost 60%. Of the earliest federal ATP projects, the rate was 80%. The Texas ATP rate is only about 11%, although it increases to nearly one-third if additional stages of commercialization are included.[108] Additional comparisons between the federal ATP and Texas ATP reveal similar results of lower commercialization in Texas projects than federal projects.[109]

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[107] This is computed as the total number of filed patents divided by the total number of projects for each program. Of course, some projects have multiple filings while other projects have none.

[108] When Texas PIs were queried about the stage of the technology or product development cycle of their project, 7% reported that commercialization was underway while 4% reported that serious planning for commercialization was underway. An additional 20% said a prototype was being developed, was already developed, or was beyond the prototype stage.

[109] One other comparison between the federal ATP and Texas ATP programs can be made from responses to survey questions posed to project PIs for each group. The proportion of federal ATP PIs reporting acceleration of the R&D cycle because of their award was 85%. A similar question ("Without the ATP/TDT award, I would have pursued development of the technology at about the same level of effort and with the same ultimate goal") generated an equivalent 70% response rate from Texas ATP PIs. A second Texas ATP question also is relevant. When asked if they agreed or disagreed with the following statement: "As a result of the funding received under the Advanced Technology Program the commercialization of technology was accelerated," about one-half of the PIs (47%) said they strongly agreed or agreed with this statement. If PIs who said the question was inapplicable are excluded, the proportion increases to slightly less than 60%.

FINDINGS

The expectation is that metrics for research grant programs that fund applied research, such as Texas ATP, should be higher than those for U.S. universities and Canadian institutions in general. Research expenditures for U.S. university R&D would support not only physical science disciplines but the social sciences and humanities, which are less likely to lead to significant commercializable intellectual property and the formation of new companies. The ratios for U.S. hospitals and research institutes also should be somewhat lower than Texas ATP because their expenditures include basic science expenditures. Federal lab metrics would also be likely to be lower for a number of reasons, including a more exclusive focus on basic science research; the administrative burden of relatively large overhead and administrative structures; a shorter history, relative to Texas ATP, of collaborative arrangements with industry; and an emphasis on security and defense technologies that are not intended to be developed commercially.

However, with other benchmarked programs, for example OARS and the federal ATP, metrics could be anticipated to be higher than the Texas ATP. Through OARS competitions, 29% of awards have been made directly to private companies since the program inception. Likewise, all federal ATP awards are conducted or led by private companies with only limited indirect university involvement. For example, universities may participate but not lead in a joint venture. Also, since the beginning of the federal ATP, less than 10% of the total funding has been awarded directly to universities.[110]

Actual findings generally confirmed expectations, although the degree of difference in some cases was greater than anticipated. Texas ATP metrics indeed were found to be superior to the general university population in the U.S. and Canada and the U.S. health and research institutes. In many cases, Texas ATP metrics were found to be far superior. From the limited federal and state program data available for comparison, the picture is mixed. In some instances, Texas ATP had lower metrics, as expected; in other cases its metrics exceeded those of other programs. It should be emphasized that all comparisons have severe data limitations.

SUPPLEMENTAL TEXAS ATP DATA

All benchmarking has been predicated on the accuracy of estimated ATP metrics. In the survey chapter, information was provided indicating that the survey responses were statistically representative of all ATP/TDT projects by research field. The survey responses were slightly different than the universe of projects on other characteristics, however, but only marginally: (1) TDT projects were slightly underrepresented (7.3% in the survey responses compared to 8.4% of all projects); (2) PIs with multiple projects were underrepresented (23% in the survey responses compared to 33% of all projects); and (3) Projects awarded in the 1987 through 1993 cycles were underrepresented in the survey responses compared to the universe of all projects. While none of these three is

[110] No university in Texas is among the top 10 universities in terms of its participation in federal ATP projects.

likely to skew appreciably the findings, the first two factors probably leads to slightly lower commercialization metrics. TDT projects are a select group with high potential for commercialization, and PIs with multiple projects presumably have more experience and operate under favorable conditions that reviewers believed would lead to successful outcomes. It is unknown if the third factor would lead to any differences.

To further probe the accuracy of the survey data and derived estimates, simple descriptive comparisons were made with previously collected information by the research staff of the Coordinating Board for Higher Education.[111] These data are shown in Table 1 under the columns labeled Texas Summary--HECB Staff. Because the Coordinating Board staff data included results from both the ATP and ARP, the ATP proportion was determined by calculating the total ATP expenditures ($320 million) as a proportion of ATP and ARP funding ($421 million) or 76%.

This assessment found higher values than the Coordinating Board for U.S. patents issued, copyrights, and start-up companies. The Coordinating Board staff compiled higher values for licenses with industry, leverage ratio, and undergraduate students. The number of graduate students was computed differently and was within the upper and lower bounds of a range.

These two sets of data were compiled through two different methods, thereby providing additional evidence, beyond that of the sample being closely reflective of the entire universe of projects, that the survey data and derived estimates are realistic.[112] While the metric values are not identical on any measure, they are close and suggest that for benchmarking performed earlier in this chapter, the estimates are reasonable.[113]

CONCLUSIONS

In comparison to the commercialization outcomes of U.S. and Canadian university and health institutions, Texas ATP ranked very highly. In comparison to other programs, depending on the chosen metric, commercialization results for Texas ATP are mixed. Due to differences in program objectives, award size, and structure, limited available data render program comparisons difficult at best, and program comparisons must be considered quite cautiously. The Texas ATP demonstrated no substantial deficiencies on any metric compared to other reasonably similar programs, however.

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111 See http://www.thecb.state.tx.us/reports/pdf/0738.pdf or visit the http://www.researchintexas.com website and click on the link, *Overview of Benefits for State*.

112 While the assessment team had access to all PI project reports and utilized them for various tasks, the outcome data in PI project reports were not used in any way for benchmarking or estimating economic benefits.

113 With regard to student involvement, the survey estimate of 7,907 to 11,174 compared to the 10,285 graduate students compiled by the HECB staff. However the survey estimate of 3,307 to 4,540 undergraduate students was exceeded by the HECB staff figure of 6,452.

Table I: Comparison Metrics: US, Canada, Federal Laboratories and Other Applied Research Programs as to Texas ATP

	per $1 billion US dollars in research expenditures													*not per billion*	
	U.S. Universities	US Hospitals & Research Inst	Canada Institutions	Oak Ridge NL (2002)	Subset of 9 Federal Labs (2002)	Lawrence Berkeley NL (2002)	Lawrence Livermore NL (2002)	Federal ATP	OARS [5]	Georgia Research Alliance	TX Summary HECB Staff	Texas ATP Impact Assessment		*TX ATP Survey Estimate*	*TX Summary HECB Staff*
												unadjusted	adjusted for inflation		
invention disclosures												2550[14]		*816*	
US patent apps filed												1997[14]		*639*	
US patents issued	98	116	53	100[2]	73	69[2]	84[2]	40%[10]			825	1199		*383*	*264*
Licenses	118	155	112	61.2[2]	97	176[2]	46[2]	51.4[11]			706	960[5]		*307*	*226*
license income (in $US millions)	30	77	15	2.7[2]	2	3.0[2]	2.7[2]	52.3[12]	23.1[7]			$120.6	$96.9	*$38.6*	
Copyrights											125	281		*90*	*40*
Newly formed start-up companies	12	11	15	17.3[1]	NA	18[3]	50[4]				216	259		*83*	*69*
leverage ratio on funding									6.1[8]	6.1[6]		2.7:1[8]		*2.7:1*	*3.4:1*
% of projects in commercialization								35 [13]				32		*32*	
Graduate Students														*7,907-11.174*	*10,285*
Undergraduate Students														*3,307-4,540*	*6,452*

Table I Footnotes:

[1] Constituting 43 companies in four years ending March 31, 2004. Averaged over a four year period ending March 31, 2004. Derived from private correspondence with ORNL staff. Based on estimated $620.3 million per year in R&D.
[2] For federal fiscal year ending September 2002.
[3] Since 1990 with 700 new jobs
[4] 50+ companies since 1992.
[5] The OARS program provides grants to universities, industry, and non-profit institutions with preference given to projects that have the greatest likelihood of being commercialized. Since the program's inception, 66% of the funding has been awarded to universities, 29% to industry, and 5% to non-profit institutions. In recent years more reliance has been placed on industry to conduct and commercialize R&D. Information provided in private correspondence with OARS staff.
[6] GRA has expended approximately $375 million in an eminent scholars program, laboratories and equipment, university-industry collaborations, and technology transfer activities. No detailed budget or economic impact breakdowns of the individual programs are available. A general leverage ratio of 6:1 is cited on the website. All industry-university collaborations require a dollar for dollar match, although the actual dollar amounts are unknown.
[7] Cumulative from FY 1992 through FY 2004 based on $1.03 million in license income and running royalties generated from the $44.58 million in contract awards. Data provided by OARS in private correspondence.
[8] Includes required matching funds of 1:1 or at least $44.58 million. Also includes other funding that Oklahoma PIs attribute, in whole or in part, to applied research support. If matching funds are excluded, then the ratio becomes: 5.1. The amount is still not equivalent to the Texas ATP data as OARS includes venture capital that universities, businesses, and researchers have received whereas Texas ATP leveraged funds are only for grants. Funds are included in the Texas ATP totals only when the other funding is due entirely to the ATP/TDT awards. One Texas PI believes that his research prior to and during the TDT project provided credibility to the potential viability of a new therapy, and thus was instrumental in leading to the $25 million donation to his institution. This amount has not been included in the Texas leverage ratio for several reasons. If it were, then the leverage ratio would increase to 2.9:1.
[9] Includes 152% of all projects. This is computed by dividing the total number patent applications filed by the number of projects, which allows for more than one filing per project, or a figure about 100%. Sub-sample is 50% of all projects.
[10] Sub-sample had average of 2 per project.
[11] 15.3% of projects
[12] This is based on one of the two sub-samples explained further in the description of the Federal ATP program.
[13] 35% of projects from a sub-sample of 119 representing 80% of the total projects.
[14] 34.3% of all projects
[15] 7.8% of projects

Table I Sources and Program Notes:

Data for US Universities, US Hospitals & Research Institutes, and Canadian Institutions calculated from Association of University Technology Managers Licensing Survey: FY 2002, Survey Summary, pages 55,57, and 59. Benchmark data for Canadian Institutions have been converted into US dollars in the original AUTM publication. Data for Texas ATP were calculated from data on the electronic survey in spring 2004. Federal lab data are for federal fiscal year 2002. Federal outcome data were provided by private correspondence with a federal laboratory manager. Federal laboratory budget data were obtained from the National Science Foundation. All values are rounded to the nearest whole number except for license income.

OARS data provided in private correspondence. Georgia Research Alliance data obtained from: http://www.gra.org/federalprivateleverage.asp

ATP data are based on $320 million in research expenditures over the 1987 through 2001 time period. To compute the ratio for $1 billion, a factor of 3.125 was applied to the total for ATP projects. An inflation-adjusted amount of ATP program funding is $398.47 million in 2002 equivalent dollars. To compute the inflation-adjusted ratio for $1 billion, a factor of 2.51 was applied to the total for ATP project impacts. The effective ratio is 0.803 ($320/$398.5).

Data also were secured from the United Kingdom for 2001 but not presented here. In general U.K. universities show somewhat higher rates of invention disclosures and patent applications filed than for U.S. and Canadian universities. U.K. rates for patents issued and income yielding licenses are very similar to U.S. and Canadian universities. The rate of U.K. spinouts, however, is 10 times greater than for U.S. universities. As noted in the publication cited below, this is strictly a comparison of numbers of spinouts, without any detailed information about the spinouts such as funding levels, likelihood of success, level of management team experience and so forth. See Annual UNICO-NUBS "*Survey on University Commercialization Activities – Fiscal Year 2001*" Nottingham Business School, pages 30-32.

The federal ATP license data are based on cumulative awards of 709 total projects, 109 projects involving licensing, and approximately $2.121 billion in federal funding as of FY 2001. Later licensing data are unavailable. For patents filed, cumulative data through FY 2003 are available: 1,171 patents filed, with approximately $2.269 billion in federal funding for 768 projects from 1990 through September 2004. The $2 billion federal funding has been matched with $2.3 billion in cost-sharing funds. It should be noted that the federal ATP program is similar to the State of Texas ATP program in name only. In addition to the federal ATP program being dedicated to R&D by companies, the size of individual awards is much greater than for the Texas ATP. Single company projects range from $434,000 to $2 million, with an average of $1.8 million. Joint venture projects have ranged from $600,000 to $31 million, with an average funding level of $5.9 million.

For other metrics, data from two samples of federal ATP award recipients were used. The first covers a sub-sample of 136 projects (17.7% of the 768 projects funded through September 2004) covering 178 companies for projects that started after October 1993 and ended no later than January 1999. Data were collected approximately two years after the ATP project ended. The federal ATP collects data from companies that received an ATP award at two, four and six years after ATP funding ends. A second sub-sample was based on the first 50 projects completed.

For further information, see e3 at: http://www.atp.nist.gov/eao/factsheet/com-success.htm and c1 at: http://www.atp.nist.gov/eao/factsheet/investment.htm

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Chapter 8: Start-Up Company Commercial Activity

HIGHLIGHTS

- Based on two independently cross-referenced sources, approximately 80 start-up companies, of which two-thirds remain active, have been newly formed to commercialize ATP/TDT technologies.
- Aggregated acquisition prices for 16 start-up company business reorganizations may approach $300 million dollars, with seven verified acquisitions totaling $184 million.
- Current full-time employees in active start-up companies as of 2004 are estimated at 160, with a current annual salary of approximately $11 million. Excluded from these totals are data from acquired, dissolved, and out-of-state companies that would be at least partially attributable to ATP/TDT.
- After preliminary discussion of the number of start-up companies, acquisition histories, and employment statistics, profiles are presented below for 23 start-up companies.
- All estimates are purposefully conservative and should be considered as absolute minimums.

INTRODUCTION

Unlike other aspects of this impact assessment, methodology and data issues become acute when determining the results of start-up companies' commercial activities. Small privately-held companies, as opposed to large publicly-held companies, are not required to make financial reports public, do not receive continuing coverage in the business press, and usually fail to leave a paper trail of public documentation that can be reconstructed to quantify a record of commercial activity. Further, organizational permutations--through acquisitions, mergers, or a variety of other consolidations--often render a company unrecognizable compared to its original incarnation. Consequently, tracking commercial activities and apportioning financial cause and effect among entities becomes extremely difficult.

Nonetheless, although it is impossible to reconstruct the histories of 80 start-up companies over the past 15 years, data and information have been collected to bring into focus a perspective of the economic activity by start-up companies that have commercialized ATP/TDT technologies. There exists very strong evidence to support the view that many hundreds of millions of dollars have been returned to the Texas economy because of start-up activity.

NUMBER OF START-UP COMPANIES

Two independent sources were relied on for data substantiating the number of start-up companies formed for the purpose of commercializing ATP/TDT technologies. After independently cross-referencing the data, the nearly identical results reinforce the reliability of the data.

First, in interview and survey responses, a sample set of PIs identified and provided background on a total of 28 start-up companies. After extrapolation, the total count of all start-ups was estimated at 76.[114]

Second, a list collected and maintained by staff of the Higher Education Coordinating Board and based upon reports filed by PIs provided an alternative source of information about new companies. The list, which identified 69 companies, served as the starting point for further detailed and comprehensive data collection about the population of start-up companies and their commercial activities.

During the course of the data collection that extended over a period of four months, a new database of start-up companies gradually was compiled by updating and incorporating information from the ATP phone interviews, TDT phone interviews, survey responses, and extensive direct contacts with PIs and dozens of individuals associated with the start-up companies.[115]

Significant changes had occurred in the composition of the database. Twenty-four new companies were added. At least 16 companies were eliminated due to errors such as the listing of industrial partners or license partners, duplicate companies because of name changes, and so forth. Verification was attempted for all companies, and the large majority of companies were sorted into an appropriate sub-category, based on discussions with PIs, company officials, and public records.

The total number of both confirmed and unconfirmed start-up companies and various sub-categories of the population are shown in the table on the next page.

[114] As the survey responses represent about 38 percent of all projects, the estimated number of start-ups for all projects is 76 (28 multiplied by 2.72, which is derived by 1 / 0.386).
[115] All entries in the new database of start up companies appear in Appendix D. All data were as of February 28, 2005.

Start-Up Companies, All Categories

Confirmed	Active, independent start-up companies	37	
	Active sold or acquired companies	16	
	Dissolved companies	19	
	Subtotal		72
Unconfirmed	Definitely due to ATP/TDT projects but probably dissolved	5	
	Probably due to ATP/TDT (Active)	1	
	Probably due to ATP/TDT (Dissolved)	1	
	Probably due somewhat to ATP/TDT (Active)	1	
	Subtotal		8
Other	Unknown if due to ATP/TDT, company not started due to ATP/TDT but portion of success due to licensed in technology, etc.	3	
	Subtotal		3
Total			83

By the complete count method, 83 total companies have been enumerated, slightly more than the number found through the survey method. However, because there is some uncertainty surrounding three of the companies, the final conclusion is that the two methods yield remarkably similar information.

A different categorization was made of the companies, based on their current operational status, and is displayed in the table below.

Start-Up Companies by Current Operations

Active, independent start-up companies	39		
Active sold or acquired companies	16		
Subtotal		55	
Dissolved companies	25		
Subtotal		25	
Total			80

Therefore, a reasonably conservative and reliable assumption can be made that approximately 80 start-up companies have been formed for the purpose of commercializing ATP/TDT technologies and that more than two-thirds are still active, continuing to bring economic returns to the state.

ACQUISITIONS

Start-up acquisition activity represents market-driven valuations. Confirmed acquisitions of the following companies, formed as a result of commercialization of ATP/TDT projects, are displayed below.

Acquired Companies and Acquisition Prices (in millions of dollars)

Confirmed and documented acquisitions	1	DTM	45	
	2	Chrysalis	34.5	
	3	Triplex Pharmaceuticals	33.5	
	4	Modulus Technologies	30	
	5	ISOA	27	
	6	Endogen	13.6	
	7	International Stellar Technologies	.5	
Subtotal				184.1
Acquisition where price is partially attributable to original ATP grant	8	Forefront Group ($160 million)	4.0	4.0
Subtotal				188.1
Acquisitions where prices could not be confirmed either due to the complexity of the transaction or undisclosed terms	9	Eliance		
	10	PSI Systems		
	11	Perceptive Scientific Instruments		
	12	Global Integration		
	13	Argus Pharmaceuticals		
	14	Eco Waste Technologies		
	15	Gene Medicine		
	16	Labnetics		
Confirmed Total				188.1

Incomplete information suggests that the aggregated acquisition price for Eliance, Perceptive Scientific Instruments, Argus Pharmaceuticals, Gene Medicine, and Labnetics may have been significant. Argus Pharmaceuticals is now part of Antigenics, a publicly traded company with 222 employees. Eliance was acquired in an all-stock transaction by MacroGenics. Gene Medicine, now a subsidiary of Valentis, licensed its IP rights for upfront payments and options of approximately $1 million. Valentis in turn, has sublicensed the rights to nine pharmaceutical firms. The known acquisition price in 1993 for the Forefront Group was $160 million. The ATP project, which did not create specific intellectual property, nevertheless was instrumental in providing a mechanism for the company and academic researchers to work closely together at an important time in the development of the company, according to the PI, who also was the firm CEO. The PI attributes $4 million of the acquisition price to the ATP project.

Although some care should be exercised to avoid reading too much into the data, it is undeniable that considerable acquisition activity has accounted for substantial economic return to the state. Confirmed reports account for more than $180 million in transactions for fewer than half of the known acquisitions. It could reasonably be anticipated that totals for all acquisition activity could approach $300 million dollars. Furthermore, the return is not stagnant and is continuing.[116]

EMPLOYMENT IN START-UP COMPANIES

The case of ISOA, Innovative Solutions for Automation, illustrates the very significant economic benefits that start-up companies have brought to the state. ISOA, profiled below, earned revenues of $370,000 in 1996 but by 1998 revenues had grown to $2.8 million. When ISOA was acquired by Rudolph Technologies in 2002, its annual revenues had reached $11 million. Beginning in 1996, ISOA enjoyed near exponential growth, with employment growing by no less than 10 percent in any one year. As a result of a steeply ascending pattern in the number of ISOA's employees, employment reached almost 50 worldwide by 2002.

ISOA's number of "person employment years"[117] for 1996-2003 was 220 excluding both its first and latest years of operations. Assuming 10 employees for 1995 and 28 employees for 2004, total employment years to date have been approximately 258. According to the CEO, the median salary for ISOA employees on the date of their acquisition in 2002 was $78,050. Therefore, an average annual salary for the entire time period may be conservatively estimated at $65,000. The total salaries for ISOA, then have been $16.7 million. With an average salary now likely to be more than $80,000, ISOA's annual salary contribution could reasonably be estimated to exceed $2.2 million.

Current employment in active start-up companies was obtained by contacting all existing active companies. A conservative estimate for the number of current full-time employees of all active start-up companies falls in the range of 156-169. The range represents an absolute minimum, and it is not unreasonable that the number in start-up companies could be twice as many.[118]

As administrative structures and lower-wage employees tend to be unaffordable or very

[116] Caution must be exercised when that data cannot be precisely confirmed. Prudence with methodology, however, does not prevent reasonable estimates of economic returns based on existing data. The $300 million estimate, while unconfirmed, is not unreasonable.

[117] Defined as one person's employment for an entire year.

[118] A question on the survey of PIs asked about employment in start-up companies. Ranges of the number of employees were offered. The minimum number of employees from this independent source of information was 79, and the median estimate was 201. As we have more complete information from directly contacting the companies, that information will be used in this report.

limited in start-up companies, it is safe to assume that a large proportion of current employees are high-wage employees. For purposes of estimation, the minimum salary for the employees can be reasonably estimated at least at $65,000 annually, and a more likely median salary estimate is $75,000. Therefore, the most conservative minimum current annual salary impact from employment in active start-up companies is between $10.1 million and $12.7 million. A more reasonable annual estimate would be approximately double that range, or between $20.2 million and $25.4 million. The estimated total salaries since program inception are based on an assumption that current employment levels have been in place for only five years. Therefore, the conservative total annual salary estimates range from $50.5 to $63.5 million, and the reasonable estimates range from $101 million to $127 million.

Timelines are unavailable for a precise calculation about total person employment years.[119] As a rough gauge, the same five-year assumption will be used. Therefore, the low end of the range would be 800 (160 current employees for each of five years), although a more reasonable estimate would be double that, or 1,600 total person employment years. These estimates are based on actual quantifiable data and a supplemental factor that takes into account company employment such as:

- DTM with more than 50 employees at the time of acquisition;
- Forefront Group--a small portion of their annual payroll of more than $22 million annually for 300 employees at acquisition time;
- Triplex Pharmaceuticals, which grew from five employees in 1991 to approximately 45 employees in 1994, and to 60 employees in 1997;
- Modulus Technologies with eight employees at time of purchase; and,
- Other current companies that are out-of-state and are partially attributable to ATP/TDT, particularly Myogen.

In addition, the sample set of 23 companies represents a fraction of the total population of 80 companies, albeit companies that have had the largest economic impacts to date.

OTHER EMPLOYMENT IMPACTS

Another major aspect of employment impact from the ATP/TDT projects is that which has occurred with industrial partners. Quantification, however, is particularly difficult because normally many different factors contribute to employment expansion. Also, time and budget constraints impose the practical difficulty of locating partners for projects that may have occurred more than a decade ago. One notable example can provide a sense of the potential employment impact for partners, which unfortunately cannot be precisely confirmed for all partners. A 1995 ATP grant and 1997 TDT award to a Texas Tech PI led directly to a new peanut drying process. The process led to the building of five new plants in West Texas by the industrial partner at a total cost of approximately $10 million.

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[119] The reader should note the distinction between a total of "person employment years" since program inception as opposed to the current annual workforce in the set of start-up companies currently active.

The plants would not have been built in the absence of the new drying process and led to the creation of 150 new, part-time and full-time jobs. Annual salaries for these jobs are between $1 and $2 million. The cumulative payroll since the plants were built, is conservatively estimated at approximately $4.6 million.

COMPANY PROFILES

Following below are short descriptions of 23 start-up companies that have been formed to commercialize technologies arising from ATP/TDT grants.[120] The profiles are intended to illustrate the diversity of the company histories, the variety in which projects have generated economic impacts, and the difficulties that start-up companies face and overcome. The profiles also are intended to offer a richer understanding of the magnitude of economic impacts directly or indirectly generated by initial ATP/TDT grants. Many quantifiable impacts from ATP/TDT projects could not be captured because of budget and time constraints, because companies no longer exist, or because of the complexity in tracing their impacts.[121]

In conclusion, the economic impacts as a result of start-up company commercial activity are estimated very conservatively and for the most part do not include any components that have not been independently substantiated. Nevertheless, the record is undeniably clear that there have been substantial economic returns to the State of Texas, and these returns are continuing.

COMPANY PROFILE: LaserSonix Technologies

LaserSonix Technologies (LOIS) was formed in December 1998 to capitalize on Dr. Alexander Oraevsky's 1997 ATP research at the University of Texas Medical Branch at Galveston (UTMB). In 2002, LaserSonix established a joint venture with Fairway Medical Technologies. The project has since become a major focus for Fairway, and Dr. Oraevsky left UTMB in 2002 to become the Vice President for Research and Development at Fairway.

LaserSonix Technologies and Fairway Medical Technologies are now working together to develop commercial LOIS prototypes for breast and prostate cancer. The prostate cancer project is being carried out in collaboration with Professor Massoud Motamedi through research supported by a 2001 ATP grant. The parent patent that protects the intellectual property of LOIS and its applications is now assigned to LaserSonix. Four additional patents are assigned to UTMB. Negotiations are underway for licensing all existing patents to LaserSonix.

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[120] The case of TheraSense is not included in this chapter because it was a result of ARP projects, not ATP or TDT. Nevertheless, it serves as an illustration of the benefits which can flow from a university-based research and development program. A short history of TheraSense is provided in Appendix E.

[121] See Appendix D.

Headquartered in Houston, Fairway is a research, development, and manufacturing company dedicated to medical devices. Occupying approximately 15,000 square feet, Fairway has optical, wet, and electronics development laboratories, manufacturing, controlled inventory, prototype machine shop, and conventional office spaces. Approximately 50 percent of all employee time at Fairway is spent on LOIS, which has a multi-billion dollar market potential. About $2.5 million in capital has been awarded to LaserSonix and Fairway, mainly through large NIH and DOD grants. Fairway is expanding the LOIS technology to other platforms such as prostate cancer, cardiovascular disease, and image-guided therapy.

COMPANY PROFILE: Endogen

Endogen, a biotechnology company, was formed as a result of Dr. Bradley McIntire's 1989 ATP research at the University of Texas M.D. Anderson Cancer Center (UTMDACC). Endogen's life science products are used in a wide variety of biomedical research settings to investigate the underlying immunological mechanisms of diseases, including cancer, auto-immune disorders, inflammation, and AIDS. Endogen, one of the top three suppliers of products related to the measurement of cytokines and chemokines (the chemical messengers of the immune system), became part of the Pierce Group of the PerBio Science Bioresearch Products Division in May 1999 in a $13.6 million cash-for-stock transaction. The original ATP technology is still active, as Pierce-Endogen continues to return payments to UTMDACC for patent licensing.

COMPANY PROFILE: Eclipse BioScience

Dr. John McGlone's 1997 ATP project at Texas Tech University on regulation of pre-pubertal pig ovarian maturation led to the formation of a new Texas company, Eclipse BioScience. The company is in the development stage and currently has no revenues while waiting FDA approval. Approximately $1.5 million in capital has been raised, with 75 percent coming from Kansas and New Jersey, and 25 percent from government grants. Texas Tech University will receive a 3 percent royalty from Eclipse BioScience, when the company concludes licensing agreements with pork producing companies competing in the $50-$100 million annual market. Eclipse BioScience officials would like to see more active marketing assistance from academia, preferably at the state level.

COMPANY PROFILE: RSET

Incorporated on February 2, 2000, RSET owns the technology developed through a 1999

ARP grant headed by Dr. Ron Matthews of UT-Austin. More recent test results validating the technology were obtained in a 2001 ATP grant. RSET is now in the process of raising more funding. Their main product, the Rotating Liner Engine, has a potential market of $50 billion in the heavy-duty diesel market.

The company has received $779,000 in seed funding to develop the prototype, with $550,000 of that amount coming from the U.S. Department of Energy. Eighty percent of the grant monies, or $623,200, have been devoted to employee salaries over the last five years. Three University of Texas at Austin professors, five UT Austin graduate students, and a few part-time undergraduates represent RSET's labor force. Five of these employees are students associated with the original ARP/ATP research, including RSET founder and director of technology, Dimitris Dardalis. Currently working out of UT Austin's mechanical engineering lab, the company hopes to acquire office space in Austin and set up manufacturing facilities once funding is secured. RSET is a member of the Clean Energy Incubator, at the Austin Technology Incubator.

COMPANY PROFILE: Modulus Technologies

In 1992, Houston-based Modulus Technologies was formed by a student working on Dr. Don Johnson's 1991 ATP project. Although the company obtained SBIR Phase I and II grants, no outside capital was raised. Modulus' primary product was its InterAgent Toolkit, a patented approach for distributing messages among computers. This software was instrumental in the development of the Java messaging platform.

Modulus operated successfully for six years, eventually supporting eight employees. In 1998, it was purchased by Enron Communications (at the time, not a formal subsidiary of Enron) for exactly $30 million. Proceeds were distributed to company owners, which included a number of university researchers. Enron's collapse led to the liquidation of the patent, which is now held by a patent broker.

COMPANY PROFILE: GeneMedicine

In 1997, Dr. Bert O'Malley launched GeneMedicine as a result of his research under a 1999 ATP grant at the Baylor College of Medicine. Initially, GeneMedicine had four employees. The company merged with Megabios in March 1999 and became a subsidiary of Valentis, with offices in The Woodlands, Texas. Valentis, with headquarters in Burlingame, California, has several dozen employees and sales of approximately $7.5 million and a market capitalization of approximately $30 million in 2004. It is listed on the NASDAQ as VLTS.

Baylor College of Medicine licensed GeneSwitch® technology to Valentis for cash and stock options worth $1 million, with additional royalties expected in the future. Valentis has sublicensed the GeneSwitch® technology to Ligand Pharmaceuticals, Invitrogen, Genzyme, Glaxo Smith Kline, LARNAX, Lexicon Genetics, Pfizer, Senomyx, and Wyeth for use in other research applications. It has also been licensed to Schering AG and Genzyme for use in the development of therapeutics.

COMPANY PROFILE: Eco Waste Technologies

Eco Waste Technologies was started as a result of Dr. Earnest Gloyna's 1993 ATP project. Eco Waste Technologies built the first industrial plant for Jefferson Chemical Company in Austin, TX. This marked the first plant of its kind in the world to decompose organic chemicals in equipment rinse water and by-product streams. This advanced technology in waste treatment involved supercritical water oxidation and sparked a new industry, which is now primarily an overseas market. The plant cost $1.1 million and paid for itself in two years, although it is no longer active. The company was later sold and now is part of a Swedish-Japanese company. The company is still actively involved in projects overseas, including one facility involving a refinery. Eco Waste paid licensing and upkeep fees of approximately $10,000 per year to the University of Texas at Austin for the rights to use the four patents granted as a result of this project.

COMPANY PROFILE: ISOA Inc.

ISOA, Inc. was started as a result of Dr. Kathleen Hennessey's and Dr. YouLing Lin's 1987 ATP research (and two subsequent ATP awards and two TDT awards) at Texas Tech University. Formed in 1994, ISOA Inc. takes its name from Texas Tech University's former Institute for Studies of Organizational Automation. ISOA holds an exclusive license to products of the International Center for Informatics Research programs and specializes in defect control in the semiconductor industry. Based in Dallas since 1995, ISOA was acquired in July 2002 by Rudolph Technologies for $27.5 million. The company's core technologies are knowledge-based algorithms used in wafer macro defect detection and classification. By enabling inspection using a personal computer and imaging system, which entails fewer inspection costs, employees no longer need to perform chip inspection via microscope. ISOA's technology also improves semiconductor chip manufacturer's process yields.

In 1996, ISOA had revenues of about $370,000 and 17 employees. By 1998, revenues grew to $2.8 million; by 1999, to $4 million. By 2002, revenues for the first two quarters' revenues exceeded $5.4 million, supporting annual salaries for 41 employees, consultants, and contractors at a cost of $3.8 million. Ten of the 41 employees were former students who participated in one of the research projects. (The five projects the PI and her co-PI received provided career-building experiences for more than 100 Texas Tech and University of Texas at Dallas students.) One-third of the employees held advanced degrees. Self-funded and debt-free, ISOA was profitable each year, and the company built a $3 million, 20,000-square-foot headquarters in Dallas, near the campus of the University of Texas at Dallas in 2000.

With its purchase, ISOA became the Yield Metrology Group within Rudolph, and the two PIs continued with the company. Rudolph focuses on design, development, manufacture, and support of high-performance process control metrology systems used by semiconductor device manufacturers. Rudolph, listed on the NASDAQ as RTEC, is headquartered in Flanders, New Jersey, and maintains a network of sales, service, and applications offices in California, Texas, Germany, Holland, France, Ireland, Israel, Singapore, Korea, and Taiwan.

Currently 28 employees work at the Dallas site, with many having relocated to Texas. Ten of the 28 employees are former students. Due to the acquisition, most of these former students who remained with the company have become millionaires.

COMPANY PROFILE: Parallel Tools

This company commercializes software developed in a 1993 TDT project by Professor Willy Zwaenepoel at Rice University. Parallel Tools was founded in 1994, and in 1996 its primary product, TreadMarks, was released. TreadMarks is a parallel programming system that allows distributed memory computing machines to be programmed as if they were shared memory machines. TreadMarks's novel feature is that it provides a global shared address space across different clustered machines, and it incorporates several innovative features, including release consistency and multiple-writer protocols, which improve system efficiency. TreadMarks has been distributed at a small cost to universities and nonprofit institutions.

COMPANY PROFILE: Pharmacyclics

Pharmacyclics Inc. was founded in 1991 to commercialize Dr. Jonathan Sessler’s ARP/ATP research on Texaphyrins at the University of Texas at Austin. In the early 1980s, Dr. Richard Miller, then a professor at Stanford University Medical Center, was treating Dr. Sessler, then a graduate student at Stanford, for cancer when discussions regarding novel therapies sparked a collaborative idea that later would launch the new company.

The technology is largely attributed to ARP research, but an unknown unquantifiable portion, according to the PI, can also be attributed to patents developed under ATP research. The original technology was licensed from the University of Texas in 1991. No royalty payments are due to the university, but milestone payments have been received, and Pharmacyclics has contributed research support to Dr. Sessler's lab. A 1995 TDT project helped develop the GMP manufacturing process used by the company, providing $100,000 in yearly royalties to the University of Texas.

Pharmacyclics has been publicly traded under the stock symbol PCYC since 1995. The company employs approximately 120-130 full-time workers and occupies approximately 64,500 square feet at its headquarters in Sunnyvale, California. The company is located in California because of venture capital funding and the cofounder's (and CEO) ties to Stanford University. Pharmacyclics has no revenues because its products are under development. Operating expenses (including salaries, R&D, and administrative costs) are about $30 million per year. The firm has raised approximately $300 million from venture financing and equity markets.

Phase III clinical trials for Xcytrin®, an anti-cancer drug using the ARP/ATP research, expects to finish enrollment by the first quarter of 2005. If all goes according to plan, the company expects to launch its lead product in 2006. A potential market of 90,000 patients per year in the United States may benefit from this new drug.

Pharmacyclics currently employs three former students from Dr. Sessler's laboratory at the University of Texas at Austin, including the Senior Director of Chemical Development and Director of Technology Development and Licensing, both of whom are also co-inventors of the technology.

COMPANY PROFILE: The Forefront Group

The Forefront Group was launched in Houston in 1987 by Dr. Anthony Gorry of the Baylor College of Medicine. Dr. Gorry subsequently received a 1989 ATP research project that proved an important ingredient for the company's key product and ultimate success. The grant provided early seed money, helped raise venture capital, was instrumental in providing a mechanism for the company and academic researchers to work closely together at an important time in the development of the company, and moved their technology along the commercialization frontier. Yet, because the ATP grant did not create specific intellectual property and was a relatively small amount compared to other funding sources, Dr. Gorry believes only a small proportion of the company's success is due to the grant. The company initially raised $2 million, and in 1990, raised $13 million in an IPO. In 1993, the company had 300 employees located in Houston, Salt Lake City, Colorado, Florida, London, France, Germany, and Ireland. Six of the employees were former students who had participated in the original 1987 research project. In 1993, Forefront had revenues of approximately $25 million per year and annual salaries of between $20 and $22 million. In 1993, the company was acquired for $160 million by CBT Systems, now SkillSoft PLC.

COMPANY PROFILE: Triplex Pharmaceuticals

Dr. Bernard Pettitt at the University of Houston and Dr. Mike Hogan at Baylor College of Medicine started Triplex as a result of their 1989 ATP project. Triplex raised $17.5 million in seed capital, Series A, and Series B financing and also established an ongoing collaboration with a large pharmaceutical company which provided about $10 million in research and development funding for three years. By 1994, Triplex had 45 employees located in The Woodlands, Texas.

Triplex then merged with Oncologix to become Aronex Pharmaceutical in 1995. Triplex owners received seven million shares in the new company. Shares were sold publicly for $4.75. Aronex Pharmaceutical then acquired Argus Pharmaceuticals, another ATP start-up company. As of 1997, there were 60 employees. In 1998 the company's shares reached $7.50, with 20 million shares outstanding, for a market capitalization of approximately $150 million. Aronex later was acquired by Enzn Pharmaceuticals and subsequently by Antigenics (AGEN) in 2001. Antigenics, in December 2004, had a market cap and enterprise value of more than $400 million, and 222 employees (outside Texas), but as far as is known, no current Antigenics products can be attributed to Triplex.

COMPANY PROFILE: Nanoridge

A new company, Nanoridge, Inc., has just been formed and has negotiated a master license from Rice University to meet demand for advanced materials (carbon nano-tubes) that have unique properties of high strength, stiffness, and electrical and thermal conduction. Dr. Enrique Barrera and Dr. Yildiz Bayazitoglu of Rice University received a 2001 TDT grant and two earlier ATP grants that served as the basis for the new company. Rice will be an equity owner in Nanoridge and Dr. Barrera will participate in the new company, which is in the process of acquiring its initial round of funding. Two companies (Nano-Tex and Stewart Automotive Research) are interested in the technology, and Nanoridge is discussing licensing opportunities with two additional companies in different industry sectors.

COMPANY PROFILE: DTM

In the late 1980s, an Austin entrepreneur, Paul McClure, approached the Center for Technology Development and Transfer (CTDT), University of Texas at Austin, in his search for a new technology to serve as the basis for a new company. He felt that Solid Freeform Fabrication (SFF) was a promising technology and, after securing worldwide licensing rights to it, formed Nova Automation. SFF was the result of a 1987 ATP project by Professor Joseph Beaman, which utilized CAD and a computer-controlled laser to actually create 3D objects.

The company developed a “beta” program of five partners (General Motors, Kodak, Plynetics, United Technologies, and Sandia National Laboratories), which provided the project with a beta level sintering machine. The program participants provided feedback and input to the ongoing development of a commercially viable SFF machine. The company, which had changed its name to DTM Corporation, unveiled the first SFF machine in October 1989. Their first product, the “SinterStation 2000,” which implemented the Selective Laser Sintering (SLS) process, was marketed in late 1993.

A variety of industries worldwide use the machines in making a broad range of components for their products. For example, Baker Hughes uses them to make drill bit housings, Siemens makes hearing aid shells with them, and Boeing, with fifteen of the machines, is planning to spin off a division that will use them in the manufacture of aircraft parts. Formula 1 race teams also use SFF technology to design and fabricate unique parts for their cars.

DTM was acquired by 3D Systems of Valencia, California, for $45 million in 2001. UT-Austin received approximately $5.2 million in licensing royalties from its initial license to DTM. At least three of the students attached to the project are still working with the technology. One works at an Austin company that uses a similar spin-off technology, and two formed their own service bureaus in central Texas that provide consulting services to the SFF manufacturing industry.

COMPANY PROFILE: Photodigm

Dr. Gary Evans’s GSE laser has the potential to significantly advance the implementation process to enable networks to upgrade to the 10 gigabit Ethernet standard. The PI, from SMU, leveraged research results from multiple ATP grants to form a company, Photodigm (www.photodigm.com), enabling its participation as the industry partner for a successful TDT grant. SMU has established an agreement with Photodigm, providing the university a small equity position in Photodigm and a payment over several years to help support ongoing research. In November 2000, Photodigm received first-round funding of $7.9 million from Corning Innovation Ventures, TriQuint Semcondutor, West Stage, Compass Technology Partners, and Arkoma Venture Partners.

Dr. Evans currently works with potential customers to beta test the product versions of their 1310 nm GSE laser, developed by the 2001 TDT funding. In addition to the 2001 TDT grant’s required matching funds, Photodigm provided SMU approximately $373,000 in cash and $896,000 of in-kind support. Photodigm has additional research contracts with other SMU professors and departments.

Photodigm currently employs 20 people, including one of Dr. Evans’s former students from the Texas grant funding. In their current fiscal year, they expect revenues of approximately $800,000. John Spencer, CEO of Photodigm, said the TDT research helped attract interest from government groups, which, in turn, has led to more than a million dollars in SBIR grants to augment their venture funding.

COMPANY PROFILE: ScenPro

SEP is a process that uses scenarios as a basis to define and formally document both user- and system-level requirements. ScenPro was established in the early 1990s to market technologies developed through multiple ATP and TDT projects by Professor Karan Harbison of the University of Texas at Arlington and Professor Suzanne Barber of the University of Texas at Austin. Although ScenPro does not license the process to any other organizations, it does employ this methodology as part of the company's research and development process. They have a long list of Department of Defense customers, two private sector companies in the defense industry and two others, including Oracle. These systems have been used in building complex manufacturing systems, as components in the launch of new commercial products by Texas companies (Techsus Medical Systems, Trilogy, Reveille, Texas Instruments, and Intellection), and in the launch of new ventures by other companies, such as CTA Incorporated and Factory Controls.

COMPANY PROFILE: Prokaryon Technologies Inc.

Prokaryon Technologies Inc. was founded in August 2002 to develop and market products that prevent and control infectious diseases in animals. The company will be using proprietary genomics-derived platform technologies, licensed from the Baylor College of Medicine in March 2003. BCM Technologies, Inc. (BCMT), the venture development subsidiary of Baylor College of Medicine, provided approximately $500,000 in seed funding.

The most economically devastating bacterial disease in the U.S. cattle industry is shipping fever (pneumonia). The technology associated with this TDT grant (Dr. Sarah Highlander was the PI), and a preceding ATP grant, deals with genetic-based vaccines for shipping fever. Based on results of the TDT project and further research, Dr. Highlander and others decided to commercialize the Baylor recombinant strain using the subcutaneous injection approach.

Prokaryon's first product, SureVax™ Mh vaccine, will use Baylor's bacterial strain and is predicted to provide greater than 70 percent protection against shipping fever compared to currently marketed vaccines. The vaccine could be approved for use by USDA Veterinary Biologics within two years, based on current approval times. The business champion for the formation of Prokaryon was Dr. Edward McGruder, who was previously a senior executive at Eli Lilly. When looking for new medical-related opportunities, he became aware of Dr. Highlander's patent and contacted Baylor's Licensing Group. This was somewhat serendipitous as Dr. Highlander's technology was outside the mainstream research areas of the Baylor College of Medicine.

COMPANY PROFILE: InnovaLight

Innovalight was formed in 2001 to commercialize the research of Dr. Brian Korgel at the University of Texas at Austin. Occupying 10,000 square feet in their Austin facilities, InnovaLight is developing solid-state lighting solutions based on its luminescent silicon nanocrystals. According to Dr. Korgel, about 15 percent of the company can be directly attributed to the 2001 ATP project. The company payroll has been supporting eight employees since mid-2003 and is looking to expand. Several employees are former students of the University of Texas at Austin, including one chemistry PhD, one undergrad, and three summer interns. Although the company has no sales revenue, between $2 million and $5 million in salaries have been paid since 2001. Between $5 million and $10 million in seed capital has been raised, with most coming from outside Texas.

COMPANY PROFILE: Selenium Technologies and Selenium Ltd.

As a direct result of Dr. Ted Reid's and Dr. Julian Spallholz's 1995 TDT research at Texas Tech University, Selenium Technologies was formed in 1996. Occupying a 2,000-square-foot facility in Lubbock, Texas, the biotechnology company supports three employees, one of whom was a student who participated in the research grant. Selenium Technologies acts as a license factory to other pharmaceutical companies, with each of Selenium's four products competing in a $1 billion market. Total company salaries are approximately $170,000 per year, and capital has been provided by the company's founders. Two additional companies have spun off of Selenium Technologies. Eburon Organics USA, formed from a merger with Eburon Organics in Belgium, will be manufacturing compounds for Selenium Ltd. (see below), which will be licensed by Selenium Technologies. A second spin-off, PharmaSE, had sales revenue of $400,000 in 2003 and $700,000 in 2004.

In 2005, a new R&D company will be formed as a result of Drs. Reid and Spallholz's 1995 TDT research at Texas Tech University. Selenium Ltd. will support 30 employees with more than $1 million in annual salaries. The new biotechnology company has raised $3 million, $1 million in the initial round, from Texas-based venture capital firm Emergent Technologies. Selenium Ltd. will be developing a wide range of Selenium products including coatings for contact lenses and heart valves, anti-cancer drugs, and bacteria-resistant antibiotics. Texas Tech University will have a 7 percent equity stake in the new firm.

COMPANY PROFILE: Eliance Biotechnology

Respiratory Syncytial Virus (RSV) infects 90,000 children and causes 4,500 deaths every year in the United States alone. There is no effective vaccine to combat it. A candidate vaccine for RSV was developed and a company, of which The University of Texas Southwestern Medical Center at Dallas is part owner, was created—Eliance Biotechnology, named for the Expression Library Immunization and Linear Expression Element. The company was the first start-up based on a technology from the University of Texas Southwestern Medical Center that was formed in and stayed in Texas (Dallas).

Eliance began operations in 2000 and received a total of $2.5 million from several venture capital firms. In June 2002, Eliance was acquired in an all-stock transaction by MacroGenics of Rockville, Maryland. After the merger, Eliance received around $10 million from two grants, one from SBIR and the other from the National Institute of Allergy and Infectious Diseases (NIAID). Eliance had nine employees in Dallas at the time of the acquisition, and that office remains operational. It now has 21 employees. Three students, one postdoctoral student, and one technician from Center for Biomedical Inventions (CBI) who worked on the original grant are working at MacroGenics. After the acquisition, MacroGenics shifted its emphasis to therapeutic products rather than vaccine discovery. The University of Texas Southwestern Medical Center received approximately $200,000 in licensing fees for the core technology and has an equity interest in MacroGenics.

COMPANY PROFILE: Chrysalis BioTechnology

As a result of his 1989 ATP project, Dr. Darrell Carney of the University of Texas Medical Branch at Galveston (UTMB) started a company called Chrysalis BioTechnology in 1995. This was the first spin-out company for UTMB. Chrysalis had an exclusive worldwide license from UTMB for several technologies and paid the university approximately $1 million in royalties, in addition to providing a significant amount of subcontracted research back to UTMB.

In 2004 OrthoLogic Corporation [NASDAQ:OLGC] agreed to purchase Chrysalis for $34.5 million in a combination of stock and cash. OrthoLogic is funding the development of Chrysalin for a variety of orthopedic and nonorthopedic indications and is currently conducting a Phase 3 clinical trial for the acceleration of bone fracture healing. UTMB, as an equity holder in Chrysalis, benefited financially from this acquisition (an estimated $1.5 million in equity value with the potential for future returns based on product sales).

The 1989 project produced other significant economic impacts. Six faculty members, two staff researchers, eight graduate students, and two undergraduate students participated in the research. The project also led to follow-on research funding of $4 million for basic research from NIH and other government entities, $3 million in SBIR grants, and $6 million in equity funding from private investors. Chrysalis also received licensing income of approximately $15 million. At the time of the acquisition, Chrysalis had 20 high-paying jobs in the Galveston region.

The success of the Chrysalis start-up also enhanced the entrepreneurial experience of both the principals of Chrysalis as well as the University, hopefully fostering the development of future startups. The research also provided an outlet for researchers to develop industry skills beyond what would normally be available to the students in a purely academic environment. And given that Chrysalis was the first UTMB spin-out, the University had the unique ability to learn about the difficulties and challenges facing a spinout company and to develop a better appreciation of the relative value of contributions.

COMPANY PROFILE: Myogen

Dr. Eric Olson, chairman of the Department of Molecular Biology at the University of Texas Southwestern Medical Center, has been awarded four ATP projects related to the signaling pathways underlying heart failure. As a result of the research, Dr. Olson and a colleague started Myogen in 2002, a biopharmaceutical company focused on the discovery, development, and commercialization of small molecule therapeutics for the treatment of cardiovascular disorders. Based in Westminster, Colorado, and occupying approximately 50,000 square feet, Myogen Inc. raised $80 million from its IPO, and the company, as of November 30, 2004, had a market capitalization of $290 million, an enterprise value of $171 million, and 57 employees (NASDAQ: MYOG). For the six months ended 6/30/04, revenues totaled $4.8 million, up from $1.4 million. Total company salaries are estimated to be between $2 million and $5 million per year.

According to Dr. Olson, the ATP grants were “50 percent responsible” for the current condition and prospects of this expanding biotechnology firm. It is located in Colorado because several of the cofounders are based in the Denver region. Approximately 20 graduate students and postdoctoral fellows worked in the lab during the course of studies, providing real world experience to strengthen the talent pool of highly trained specialists in Texas. Two post-doctorate fellows went on to be lead scientists, one for Myogen and one for Novartis, as a result of their work on the ATP project.

COMPANY PROFILE: Carbon Nanotechnologies, Inc.

Based on three ATP grants in 1995, 1997, and 1999, Professor Richard Smalley of Rice University formed Carbon Nanotechnologies, Inc. (CNI) in Houston to provide a commercial source for carbon nanotubes. Created in early 2000, CNI licensed from Rice all rights to the intellectual property that Professor Smalley and his group had developed at Rice. Under the licensing arrangement, Rice has equity in CNI and receives royalties on products sold by the company. Dr. Smalley and Dr. Ken Smith, colleagues in research and development of carbon nanotechnology at Rice are two of the founders of CNI.

CNI currently has 30 employees, 10 contractors, and 10 consultants who have worked closely with the company. In April of 2001 CNI announced $15 million in angel investor funding so they could begin producing significant quantities of buckytubes. CNI has expanded to include approximately 7,500 square feet of space in the Houston area: 1,500 for operations and 6,000 for manufacturing. The National Institute of Standards and Technology (NIST) granted a joint award of $3.6 million to CNI, Motorola, Inc., and Johnson Matthey Fuel Cells, Inc. in September 2004.

According to Professor Smalley, "The Texas ATP grants to us here at Rice were absolutely crucial to the spawning of this company and its early success."[122]

[122] This was included in email correspondence from Professor Smalley, dated November 29, 2004, to a research team member.

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Chapter 9: Additional Analyses and Information

9.1 Review of Technology Transfer and Commercialization Goals in TDT Announcements and Proposals

HIGHLIGHTS

- A representative sample of selected proposals was closely examined.
- Proposals should require more detailed plans for the development and transfer of the technology.
- More review panelists should have business and technology commercialization backgrounds.
- Collaboration of university technology transfer licensing officers in the preparation of proposals should be encouraged.

INTRODUCTION

The stated purpose of the Technology Development and Transfer (TDT) program is to support technology development and the transfer of that technology to the private sector. During each two-year cycle, a program announcement describes the TDT program's goals and provides application directions to principal investigators (PIs) considering grant submissions. The commercialization of technology involves prospective planning and execution under speculative circumstances, tasks typically outside the realm of applied academic research. Based on interviews conducted with all TDT PIs and an initial review of outcome data for the TDT projects, it appears that some TDT projects were indistinguishable from ATP projects in their commercialization orientations. In light of these facts, the research staff undertook an additional task involving a ranking procedure performed on the commercialization and technology transfer sections of a representative sample of TDT proposals that had been successfully reviewed and awarded funding. An analysis of the ranking procedure and its implications are discussed fully below.

ANNOUNCEMENT REVIEW

The biennial program announcements for the Technology Development and Transfer (TDT) program have remained essentially unchanged from 1993 through 2001, except for two revisions made in 2001.

First, in the *Restrictions* section for the pre-proposal, the following sentence was added: "The industrial partner must be committed to commercializing the technology." Prior to the 2001 revision, commercialization in Texas had been expressed as a preference.

Second, a *Matching Contribution Evaluation Form* was included among the TDT proposal evaluation criteria. Item number five on the newly included form solicited information to be used to evaluate the capacity of the industrial partner to commercialize the technology.

The two revisions emphasize that commercialization of the technology had become an increasingly more important goal of the program.

CRITERIA FOR AN OPTIMAL COMMERCIALIZATION PLAN

The *Description of Research* section accurately recognizes key factors faced in commercializing a disruptive technology. Section B, *Product, Process or Service*, requires both a precise definition of the product and a market assessment, two essential initial steps in the commercialization of technology. Appropriate protection of the intellectual property is required, notwithstanding the proprietary concerns of the institution that owns it. In section E, the *Development and Transfer Plan* section, an explicit description of how technology transfer will occur is required following the two-year plan for developing the technology and its transfer to a commercial entity. The clear implication is that this planning, along with the identity and background of the participants and their roles, should ensure that a well-designed commercialization effort is forthcoming.

PROPOSAL RANKING

A random sample of TDT proposals was selected for ranking from the group of projects considered promising. In arriving at a 19 percent sample set, more recently submitted proposals were chosen, and, due to the relative proportions of institutions in the data set, Texas A&M University and the University of Texas at Austin are over sampled. The random selection process included two proposals, in different years, by the same principal investigator.

A total of 29 proposals were selected for ranking from among the total of 156 TDT proposals. The ranking was conducted by a team of three project staff members, all of whose educational backgrounds include a Masters of Science in Science and Technology Commercialization from the IC^2 Institute of the University of Texas at Austin. The purpose of the ranking was to make an independent evaluation of the 29 selected proposals in terms of certain aspects of the criteria ostensibly applied originally during the review panel's project selection process. Following the initial ranking, significant outliers in the sample set were reconsidered, and the results were then moderated. Variances within acceptable ranges resulted for nearly every one of the 29 projects ranked by the team.

The team proceeded by evaluating particularly the plan for technology transfer, which consists of a chain of activities that bring research to the marketplace. However, it is difficult to arrive at an exact definition of technology transfer and even more difficult to measure its accomplishment.[123] Two concepts—the fulfillment of specific public needs with innovative knowledge and the application of knowledge into particular products and services—were merged into the notion of moving raw technology from an innovator toward a capable producer. That notion was adopted for the purposes of the evaluation of the technology transfer plans in the TDT proposals.

Classifications of the Sample Set of 29 TDT Proposals Ranked by the Assessment Team

Proposals by Institution

University of Houston..2
Texas A&M University..7
Includes Texas Engineering Experiment Station and
Texas Agricultural Experiment Station
Baylor College of Medicine..2
Texas Tech University 2
The University of Texas Health Science Center at Houston 1
The University of Texas at Austin..8
William Marsh Rice University 3
The University of Texas Southwestern Medical Center at Dallas................1
Southern Methodist University..1
The University of Texas at Arlington 1
The University of Texas Medical Branch at Galveston................................1

Proposals by Targeted Research Area

Microelectronics 4
Aerospace..2
Biomedicine 7
Energy..2
Agriculture & Aquaculture 3
Transportation..1
Biotechnology 4
Telecommunications..1
Materials Technology 1
Manufacturing Technology..2
Environmental Science & Engineering..1
Computer and Information Engineering 1

[123] Gibson, David, and Rogers, Everett. 1994. "Technology Transfer and MCC." Chapter 5 in *R&D Collaboration on Trial: The Microelectronics and Computer Technology Corporation*, Boston: Harvard Business School Press, 328.

Proposals by Year

1993 7
1995 3
1997 5
1999 3
2001 11

Ranking of Proposals Primarily on Sections: "Product, Process or Service" and "Development and Transfer Plan"

Good 9
Mediocre 10
Poor 8
Unusual 2

RATINGS/FINDINGS

An initial ranking determined that at least one third of the *Description of Research* sections were relatively well documented. Two other sections, *Product, Process, or Service* and *Development and Transfer Plan,* however, often appeared to lack sufficient input in describing workable plans to "transfer the technology to the private sector."[124]

Although a proposal is less detailed than a strategic business planning document, the essence of the analysis that goes into a business plan would be expected to appear in the corresponding sections of the proposals. However, many of the ranked proposals did not include any basic preliminary market research. One merely referred to two generic studies of market research, and others offered little explanation of potential economic benefit to the research institution or to the State of Texas.

Nine of the proposals clearly articulate the technology and the proposed state of its development at the time it would be transferred to the industrial partner. Proposals offer statements such as "Transfer produced material to [industrial sponsor] for internal/external testing and market evaluation," adequately describing the responsibilities of the PI's team and the industrial partner's team. Another proposal offers as a milestone the "deliver[y of] a packaged [technology] to industry co-sponsors," thereby stipulating a functioning prototype to be delivered to the sponsor within a particular timeframe. Thus, many proposals clearly spell out technology transfer plans that are easy to understand and measure.

Potential difficulties and challenges in executing, defining, and scheduling the technology transfer of a particular research project are evident in more than half of the proposals ranked. At least five proposals include statements alluding to a step simply by concluding with the statement "and transfer that technology to industry." Although a plan must move forward expeditiously, it must also allow room for delays and detours.

[124] *2001 Program Announcements – Background.*

One proposal addresses the technology transfer plan in six-month time segments. Each segment depends on the timely completion of the previous step, leaving no room for error in planned events and leading to the industrial sponsor and university researchers scaling up within the following six months. No provision is made for contingencies or unexpected circumstances. Often, only statements such as “present the results,” “collaborate with sponsor,” and “support sponsor” are provided, with inadequate detail about what is transferred or what is to be done with what is transferred.

Eight of the ranked proposals were rated as poor. All eight substantially ignored the *Transfer Plan* section and substituted in the *Development* section an explanation (or further explanation) for the research plan. As an example, one proposal ended the section with the statement: “To ensure that the advanced technology developed under this project is widely accepted and implemented an informative brochure will be developed describing the advantages of the new system.” Precise statements about marketing literature are unrealistic at this stage of the commercialization process.

Two proposals were notably atypical and were accordingly ranked “unusual” in their approach to technology transfer and commercialization with benefits not well balanced among the participants. In the first example, a 2001 microelectronics research proposal, the industrial sponsor provided nearly $900,000 of in-kind support in the form of salary for six of its employees who were to work in the university clean room alongside academic research personnel. A portion of $600,000 in cash was to be used to upgrade the university’s clean room. In effect, the proposal provided the sponsor with inexpensive access to a clean room and research support from the PI and graduate students. The company anticipated receiving Series B funding before the end of 2001 that would have made it possible to relocate operations from the university. No mention was made of the method by which technology transfer would continue if and when the relocation occurred or of precisely how commercialization would lead to “anticipated profitability by the fourth quarter of 2003.”

In the second atypical example, a 1993 aerospace proposal took proprietary information from two marketing plans developed by MBA graduate students at the University Center for Business Administration. The proposal identified the market size, potential customers, probable applications, pricing, and other markets and submarkets, i.e., indispensable information for commercializing a technology. In the *Development and Transfer Plan* section of the proposal, the development and testing phases of the technology were clearly addressed. The section concludes with the statement “should promote a fast commercial expansion of this technology.” No information, however, is provided as to how exactly the technology could be brought to any of the markets identified in the two marketing plans.

RECOMMENDATIONS

The procedure for TDT application review and approval as it is currently implemented in the review of technology transfer and development plans is not defective, however,

improvement is advisable. Three steps could be taken to bring more beneficial scrutiny to panel reviews.
First, on the issue of interaction with tech transfer office personnel, in a paper on technology transfer at MCC, a researcher stated:

> Technology transfer is such a buzzword. People think that you can just tie it [the technology] up in a package, and I could just hand it you; I would then forget about it, and you would open the package and say "Wonderful." It just doesn't happen that way. It's a difficult problem, and it takes dedicated people.[125]

The distinction between a static transfer and a dynamic collaborative transfer is well understood by technology transfer professionals. The importance of the distinction is the difference between a transfer that is crafted and one that is off-loaded. Because the expertise of technology transfer at universities resides primarily in the staffs of respective technology licensing offices, future TDT proposals could be improved through the involvement of licensing officers. Most technology transfer offices or technology licensing offices are understaffed and under funded. However, if this major problem could be overcome, there would be an improvement in the TDT proposals and the quality of the projects selected. Furthermore, technology transfer plans incorporated in the TDT proposals would be more likely to succeed if ultimate marketing and product development strategies were anticipated by applicants with the help of technology transfer licensing officers.

Second, of the 72 panelists sitting on review panels in 2003, 61 percent are academics and 13 percent are employed at federal laboratories. Only 26 percent came from the for-profit sector. For the purposes of TDT proposal evaluation and review, a larger proportion of reviewers from private firms would be beneficial, including some proportion who are from smaller start-up companies rather than large corporations. As a pilot test, it may also prove worthwhile to include a small number of technology transfer specialists and marketing specialists who may review only pertinent sections of the proposals. A final possibility would be to include one or more venture capitalists in the review process. While many professionals are unlikely to be interested in reviewing a large number of proposals, some members of a particular industry might welcome the opportunity to provide input.

Third, the articulation of the requirements for adequate responses to some sections of the grant application warrant reconsideration, particularly the product, process, or service section and the development and transfer plan section. More specific directions for some sections would lead to more efficient reviews. Perhaps a checklist of specific points reviewers should key on should be developed in order to moderate the results of review. The independent rankings raise questions about whether a standard of greater scrutiny should be brought to bear during the review of the applicant's plans for business development and technology transfer.

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[125] Gibson and Rogers, 329.

CONCLUSION

Steps can be taken to enhance the proposal review process in order to elicit more realistic technology transfer plans from applicants. Further, the representation on review panels of a wider spectrum of technical business and commercialization backgrounds outside of academia would likely lead to enhanced commercialization outcomes for TDT projects.

9.2 Other Economic Benefits

HIGHLIGHTS

- Data from the principal investigator (PI) survey indicates that about one-quarter of the projects have led to the adoption by an industry partner of a new or improved process, produced cost savings, helped to avoid a cost, or enhanced an existing product.
- Approximately $108 million in tangible economic benefits have accrued to industrial partners and other stakeholders outside the universities as a result of ATP/TDT projects.
- Additional significant, unquantified economic impacts also were identified and not accounted for elsewhere among the total benefits of the projects.

Principal investigators were asked to identify any economic benefits that accrued, not directly to their respective institutions, but to any other stakeholders. The beneficiaries could have been the companies that had served as industrial partners in financial sponsorship of their research, other companies, or even entire industries.[126] A variety of possible benefits were cited: a new process or improvement of an existing process, cost savings, cost avoidance, or a product enhancement. Based on responses for nearly 450 projects, slightly more than one-quarter (27 percent) of the projects have led to the adoption by an industry partner of a new process or improved process, produced cost savings, helped to avoid a cost, or enhanced an existing product.

PIs were asked to quantify a specified amount or value of the benefit or, if unsure, they were asked for an industry partner reference. The total benefit has been calculated at $40.03 million for survey respondents, and for the total universe of projects, the benefit is estimated at $108.9 million.

To further investigate, interviews were conducted with a sample of industrial partners on projects where no dollar amounts were estimated. The eleven projects covered by the

[126] Because PIs were reporting on experiences and benefits for others, the data collected is considered less robust than that for many other survey questions. Nevertheless, many of the largest benefits have been verified, so any errors are likely to be minor.

interviews included six projects that led to product enhancements and five projects that centered on process improvements. Based on the interviews, economic impact for the eleven projects falls into four categories: projects with confirmed estimated dollar amounts (six projects), those with anticipated future impacts (two projects), product enhancement projects that were implemented but were unsuccessful (two projects), and one recent process improvement project the impact of which is difficult to estimate.[127]

The industrial contacts who were interviewed confirmed that two of the six product enhancement projects and four of the five process improvement projects have provided clear measurable economic impacts. The estimates provided by the PIs were quite similar to those provided by the industrial partners. For two projects that involved research in the area of robot manipulators and motion controls, the industrial sponsors confirmed that they used the results of the research to secure subsequent contracts. Another project involved a food extrusion system and is described below.

Dr. Rosana Moreira's 1993 TDT project at the Texas Agricultural Experiment Station has resulted in a significant competitive advantage for Frito-Lay of Dallas. Because of an established relationship between Frito-Lay and Texas A&M University, Dr. Moreira and others approached company representatives about a new direction of research. Upon completion of the project, Frito-Lay implemented a computerized process control for a high quality food extrusion system on one of their product lines. This TDT-developed technology has reduced crewing and processing costs by $400,000 to $500,000 annually. Since the technology's implementation, Frito-Lay has saved $4-$5 million. Even more important for the company was the significant improvement in product quality, the benefits of which, however, company officials were unable to estimate. Frito-Lay has implemented the technology in several other plants and product lines elsewhere in the United States. This project would not have occurred had the TDT program not existed. When first approached, company officials felt the project was very interesting, but also too risky for them to support on their own.

The process improvement projects represent more than $2 million in recurring annual savings for the industrial partners. One of the projects focused on developing methods to diagnose and then resolve low frequency noise defects in an infrared detector made by the industrial partner. The products are very costly to make and the partner had achieved only a 10 percent yield on processing runs. The research project provided an improved processing technology that more than doubled the yields, saving the company about $2 million a year over at least four years.[128] The other two projects involved process

[127] The results from one ATP project have been implemented in the industrial partner's design process, which has speeded up their new product design process. The sponsor could not determine a specific dollar amount for this benefit, however.

[128] The subsidiary was divested in 1997, and although it appears the product may still be sold to the military, it was not possible to verify either continuing savings or that the current product is based on the original project.

optimization technology that a large chemical company has used. It is estimated that these two projects, combined, are generating annual savings of hundreds of thousands of dollars.

Two of the six product enhancement projects have led to products that are in the final stages of the commercialization process and offer the potential of significant future benefits for the industrial partner. One of these two products is a Texas A&M process improvement technology with the potential to allow the conversion of waste biomass at costs low enough to provide a competitive alternative energy source. The industrial partner, Terrabon, Inc., is a start-up company that recently received a very positive engineering feasibility report validating the concept and the demonstration plant construction costs.

Because the survey question did not differentiate between economic impacts that could represent recurring annual cost savings or only one-time savings, it is unknown what proportion of the estimated $108 million in benefits is annual and recurring. At least two of the larger economic benefits included within the $108 million were recurring for at least several years.

Beyond the quantified economic benefits, more than 75 other PI responses pertained to possible economic impacts and are presented, as individual entries, below. Each entry is a direct quotation from an individual PI. These statements show the likelihood that there are numerous examples of actual benefits. However, because there is no quantitative estimate, the benefits were excluded from the totals rather than be arbitrarily valued. The entries in total clearly paint a picture of unquantified financial return to the State of Texas as a realized dividend of successful TDT projects.[129]

Comments made by PIs concerning unquantified economic benefits include:

> *Unknown but large amount indirectly, through acquisition of unprofitable business and turning it to profitable using TDT technology within a year.*
>
> *This is based on other financial support for research received since that time and the likely impact on an approved clinical assay for telomerase. Should FDA approval be obtained, UT Southwestern and UT System has the proprietary rights to this technology with an exclusive license to a publicly-traded company and we (Texas) would receive significant royalties. This was an estimate you asked for and this is what I think is likely to happen over the next 3-5 years.*[130]
>
> *Part of the project was to develop a UV laser suitable for geologic applications. Our collaborator was Merchantek, out of California. The laser design and implementation became very popular in geology and*

[129] To clarify further, these entries were not included in the summary total of $108 million in other economic benefits but are unquantified benefits.
[130] A $4 million estimate was not included because the benefit has yet to occur.

analytical chemistry circles so that the multimillion dollar revenues from laser sales resulted in Merchantek being bought out by New Wave, also not of Texas.

Plexon Inc. (at that time Spectrum Scientific) of Dallas collaborated closely with us at UNT. This early exposure to nerve cell network dynamics and the problems associated with multichannel recording, and data storage, data processing, interpretation, and display provided a strong foundation for Plexon Inc. Plexon is now a premier supplier of multichannel hardware and software worldwide.

The graduate student on the project went to work at Excel meat packing. They have at least two plants that process 3,000 cattle per day. He used the technical information gained by studying evapotranspiration to reduce evaporation from carcasses. It saved an average of five lbs per carcass.

Concepts incorporated in existing processes to enhance performance.

Cannot estimate. A number of companies have adopted our work into their products.

I cannot determine, but the company has saved a great deal in internal R&D and lost revenue.

The industrial partner is beginning to use some of the research techniques that we developed together, so it is hard to say. It certainly has represented an advancement for applied environmental sciences, even though its economic impact cannot be estimated.

This is hard to quantify. Our work led to better understanding of a widely used method of well stimulation in the petroleum industry. That method is used in probably tens of millions of dollars of applications yearly. It is hard to quantify how much of this is due to our research project, however.

The work that we did in that project was some of the earliest research in the area of scan vector compression. As a result of that research and other subsequent research (including research that was done by the R&D group in Mentor Graphics), commercial products using scan vector compression technology have come into the marketplace and have provided large cost savings to many semiconductor manufacturers (including many in Texas). How to value the economic benefit of that one project, which was a stepping stone toward the development of the commercial technology, is hard to do.

Royalty payments totaling approximately $500,000 have been received by the University to date as a result of these projects. This should continue for approximately seven more years until the patent expires.[131]

We have worked toward better understanding infections of astronauts, which is very important. We have shown that both the virulence of the organism as well as the host responses are altered under microgravity environment resulting in severe infections that affect productivity of the astronauts. Such studies would help in designing better agents to control such infections.

This provided a rapid field test for Aflatoxin at a time that Texas desperately needed an assay. It was a great service to a large number of Texas ag and dairy agencies when the first aflatoxin disaster hit the state.

Citrus industry and consumers of Texas will obtain major benefits. Health benefits of flavonoids can be explored to prevent diseases.

It pushed my industry partner to apply for and receive several levels of SBIR funding from the federal government, which expanded their company and products.

Increased collaboration between University researchers and the microelectronics industry has led to new analytical approaches to diagnostics and metrology that have greatly enhanced process.

Our preliminary findings suggest the feasibility of a tumor gene therapy strategy and a meaningful advance in the treatment of pancreatic tumors. The results obtained from this proposal set the stage for a new set of experiments with in vivo and in vitro islet engineering and could be applied to other tumor treatments.

The funding of a Transgenic Technology Facility enabled us to acquire the necessary equipment and trained personnel to develop a core facility for the creation of transgenic and knockout mice. This is an extremely important technology in biomedical research, which has enabled investigators on this campus to move to the forefronts of their fields. This has also enabled these researchers to be competitive for grants from both federal and non-federal sources.

Development of an industrial network of partners with the university.

We have helped Texas companies become world leaders in the area of polymer nanocomposites.

[131] Only $500,000 accounted for as license income because other funds have yet to be received.

Has contributed to the improvement of cotton varieties.

Improved food safety, possibly resulting in less associated litigation.

TDT award will likely be a major factor in the successful development of a new Texas energy company.

I am very confident that my project will address a major diabetic eye caring issue that would cost the Texas Medicaid significantly.

Improved revenues for land holders and severance taxes to state of Texas. Improved success of oil and gas companies drilling in Texas.

It provided the opportunity for patients to have access to an experimental treatment for a disease for which there currently is no successful treatment and the data to date suggest that progression of the disease has been delayed or stopped. This has defrayed their costs for treatment resulting from further debilitation.

Safer industrial operations involving heat exchange fluids and other heavy industrial fluids.

A more refined version of our digital imaging system now is in common use in ecological studies in Texas and elsewhere in the U.S.A. This system, like our prototype, is fast and accurate and has replaced an unreliable older method. Digital analysis now is the preferred method of analyzing irregular areas in ecological communities.

Development of new technology to determine susceptibility to cosmic ray induced upsets in integrated circuits.

Technology that will lead to cleaner diesel vehicles, of great need in the greater Houston area.

This project is very important in resolving environmental health problems as a result of chemical exposure.

Research led to development of low-cost, growth-promoting fish feeds to enhance the profitability of aquaculture.

Better understanding of iron deficiency stress and plant adaptation to Fe deficiency stress have beneficially influenced the turf grass industry, though the actual economic impact is difficult to gauge.

The economic benefits of my project are difficult to estimate because the assessment of higher rates of feedlot manure than commonly applied were *found to be feasible. This encouraged large feedlots to disperse huge stockpiles of manure over the next decade and avoid costly environmental impacts from nitrogen and phosphorus losses to streams and rivers in the region. Farmers were the beneficiaries of low-cost plant fertilizers as a result.*

The handling/treatment procedures for harvesting and processing of oysters developed under this ATP project have led to a safer and more wholesome food product and thus led to fewer health problems related to raw shellfish consumption.

We have developed a new technique for breath analysis that may save thousands of infant lives in the United States every year. Hard to put a cost figure on this.

Interested companies learn of other projects and other collaborators in the institution. Such interactions often result in sponsored research agreements.

This research developed models and methods for creating minimum-cost, capacity-needs-matching all-optical networks, which can: (1) yield dramatic savings for service providers and (2) give equipment manufacturers a bidding advantage in competitive situations. Budgets for telecom networks are on the order of $100s of millions, and savings can be substantial. For example, I have witnessed a situation where this type of computer-assisted network design technology (similar in nature to that studied under the ATP, but for a different type of network) saved a customer nearly half a billion dollars in equipment costs.

Without this funding, we would have never discovered a new NOx reduction technology and no one in the world has tried the fuel we have tried in achieving 90 percent NOx reduction. We will continue this effort with other funding sources.

We have closely worked with [name of pharmaceutical company]for developing new polymer materials for controlled drug delivery. We have obtained many interesting results and published some important papers. Specific economic benefits may be seen within five years including integrating new processes and new chemical compositions into new products.

9.3 Proposal Review and Evaluation Process

HIGHLIGHTS

- The large majority of PIs is either satisfied with the ATP/TDT program as it exists currently or would like to see the program expanded without any changes.
- Slightly fewer than one of every five PIs commented negatively on the proposal review and evaluation processes.
- Verbatim comments about the proposal review and evaluation processes are reproduced.

One survey question asked Principal Investigators, "What, if anything, should be changed to improve the ATP/TDT program, and why?"

Comments were received from nearly 400 PIs. Responses were coded into categories. The table below, "Categories of Possible Changes in ATP/TDT As Suggested by PIs," illustrates the general views of the PIs. The top two types of homogenous responses were for "no change" or "increased funding." A third, heterogeneous category of comments about various administrative subjects is addressed below.

In general, none of the categories of comments could be viewed as negative, and, in fact, the program and its administration receive very positive feedback from most PIs, with one exception: slightly fewer than one of every five PIs commented negatively about some aspect of the proposal review and evaluation processes.

Because the primary purpose of this assessment was to determine the outcomes of projects and not to perform a traditional program evaluation, the feedback from PIs about the proposal process was not examined in depth. Comments offered from PIs are presented verbatim below. Obviously, many of the comments are probably not new, and clearly, many would require additional resources to implement. In fact, few PIs made any suggestions for specific solutions to the problems they identified. Although negative comments might be dismissed as "sour grapes" by PIs whose research proposals were rejected, it should be remembered that these comments are from PIs who have had at least one proposal accepted.

Several subcategories of responses were received. Twenty PIs thought review criteria were applied inconsistently. A different group of 20 PIs felt reviewers were unqualified to review proposals in the research area in which they were competing. Another 12 PIs had criticisms of the pre-proposal process, and a variety of other types of criticisms were offered.

Categories of Possible Changes in ATP/TDT As Suggested By PIs

			#	%
1. Increased Funding			89	23%
2. No Changes Expressed			90	23%
3. Review Process				
	a. Pre-proposals	12		
	b. Reviewer background	20		
	c. Inconsistency	20		
	d. Allow PI to rebut review	2		
	e. Reviewers lack long-term focus	4		
	f. Improve reviewer feedback	7		
	g. Other	10		
	Review Process subtotal		75	19%
4. Administration				
	a. Commercialization support	25		
	b. Grant terms and cycles	34		
	c. Expand competition	7		
	d. Categories	16		
	e. ARP comments	11		
	f. Students	8		
	g. Other	9		
	Administration subtotal		110	23%
5. Multiple Category Response			22	6%
			------	-------
			386	100%

Please note that comments below are verbatim from PIs, except for instances in which there would have been substantial confusion. In those cases, minor changes have been made by the project team for clarification only. Entries with terminology such as "he" are from interviews with PIs by project staff.

<u>a. Pre-proposals</u>

1. *(a). Revise the 1,000 word "pre-abstract" so that viable information can be given. Right now it makes the whole pre-competition a simple "crapshoot." (b). Strip all information about institution from the proposals for review. Serious bias in reviews seems to come from assuming UT Austin and TAMU are better than other institutions,*

giving an unwarranted advantage. Minimize this advantage so that the best projects are funded as opposed to the "best" institutions.
2. *Allow more pre-proposal information.*
3. *Application should show evidence of promising preliminary results.*
4. *Go back to original proposal system. The extremely short "pre-proposals" are extremely inadequate for a valid review.*
5. *I am not sure about the value of the pre-application process.*
6. *I think that the ATP/TDT program should allow for more elaborate project descriptions, followed by rigorous (NSF-type) peer review. This will enhance the stature of the program while ensuring that really good projects get supported.*
7. *Plan for current program not very clear since pre-proposal process was implemented. Is the selection for full proposals based on technical merit, on economic potential for the State, or what? This whole process has been rather murky since its inception.*
8. *Since my grant [was] awarded seven years ago, the review processes have [changed]. I feel that the pre-proposal system does not provide enough information for the reviewers to select the best grant.*
9. *The application process and forms do not lend themselves to preliminary data. I had such data that, according to the recent-past review of TDT, was needed to get the additional funding I needed to take a product to completion. This was unfortunate. Either you make preliminary data a requirement or emphasize that it is not necessary to the reviewers.*
10. *The present pre-proposal procedure is very poor. One cannot properly explain one's ideas and expertise in the very limited space allowed, so that selections for full proposal submissions are just a matter of luck. Since the new scheme has been introduced, I have felt that my weaker proposal was generally selected for the second round. I served as a proposal reviewer for a similar type of program for the state of Indiana a couple of years ago, and I feel that their system (perhaps modeled on the original Texas ARP/ATP) is much better than the one we now have.*
11. *The proposal format should be changed to NIH style and possibly "fast lane" review.*
12. *With the density of proposals for ATP grants, it is almost random luck to receive funds. It is hard to get good reviews. I would like less paperwork per proposal. Because of the diversity of proposals, evaluation is very difficult. I would like to see some explicit expectation of societal benefit--environmental, social, cultural, economic, or public education.*

b. Reviewer Backgrounds and Qualifications of Reviewers

1. *Backgrounds of proposal reviewers are too confined.*
2. *Better reviewer background—but the areas are so broad, I don't know if this is possible.*
3. *Have more qualified reviewers.*
4. *I strongly feel the current review system is not adequate. I can tell some reviewers do not know the subject matters enough to make proper judgment. The program should follow the NSF model of asking proposal submitter to recommend a list of referees.*

5. *Ensure reviewers are well versed in the areas they review.*
6. *It needs broader and more knowledgeable reviewers.*
7. *More knowledgeable reviewers in each specific area because this is the most frequent complaint heard about this program.*
8. *More knowledgeable reviewers with industrial experience.*
9. *The peer review process could be improved to obtain (possibly mail) reviews from experts in specific areas. Panels with broad scope too often tend to be superficial.*
10. *The review system needs to be improved. The quality of reviewers is not clear. Some comments I got from my subsequent submitted applications were totally out of line. I strongly wonder whether the reviewers had the broadness and depth in understanding the applications.*
11. *Use the experts to review the relevant application.*
12. *The reviewers for the competition in 2003 did not seem to have the breadth of knowledge required to review the program. Add more reviewers who understand and hence can accurately review the proposed research.*
13. *When he writes a proposal to the National Science Foundation, he knows that the judges will be experts in that field. As a result, he can tailor his proposal to them and refer to things (ideas, publications) that they are familiar with. However, no one has any clue as to who the ATP judges are—are they experts in the field or not, no one knows!*
14. *He is very happy with the program, calling it "excellent." However, he believes the evaluations are poorly executed because the project is often put into the hands of the wrong group of people. He would like to see a better screening process.*
15. *The current method to be invited for ATP program is not a fair method for development and application projects in medicine. The initial reviewers may not be experts in the field. Based only on the abstract, it is very difficult to judge whether the project is worth doing or not. He feels that the new way by which projects are reviewed—by the researcher submitting an abstract only instead of a more comprehensive idea—is not beneficial. Additionally, he said that often the ATP reviewers say that XYZ project should be an industrial project instead of a research project. He felt that this was bad because it forces him to work with industry. It restricts the freedom of the professor. It allows the industrial sponsor to be the JOINT patent holder at a later stage. Finally, he felt that the current ATP reviewers have a narrow area of expertise, and they cannot fairly evaluate the proposals made to them. In the past at least one person from his department had been awarded an ATP grant at any given time. Now that is no longer true.*
16. *The ATP program should follow up and provide additional funding to promising and successful projects already funded in the previous funding cycle. The reviewers of the last cycle seemed to be out of touch with the proposals reviewed, the purpose of the program, and other factors. Even using their own words, their reviews did not reflect on the reviewed material—even the title of the submitted proposals... In general, there should be more capable reviewers who understand the technology path and better allocation of resources with follow-up support on an as-needed basis if the researcher is showing substantial progress.*
17. *A more complete set of reviewers with broad interests and unbiased opinions. Awards should be based strictly according to merit, nothing else.*

18. *Better reviewing process with many experts in the [area]. Right now, there are very few people in the review process and they make arbitrary decisions and there are no checks on how well the reviewers have done.*
19. *Get more technically competent reviewers.*
20. *Hire more reviewers in more diverse fields. The number of reviewers are hardly enough for the diverse set of proposals submitted to the program. If that is not feasible, focus the research funding into fewer areas, then it will be easier to find better matching of reviewers.*

<u>c. Inconsistency in Reviews</u>

1. *I think when it works, it is fine. There is a rather random nature to what gets funded in any one cycle and I really don't see a way around this. I do like the brief proposals and the pre-proposal screening to minimize the work for all involved.*
2. *Improve the review process. Review quality ranges from excellent to ill-informed.*
3. *Many faculty members believe that the approval process selects grants for approval with a rather great degree of randomness. If this is true, the process should be changed to depend more on quality of the application.*
4. *More consistency in review process year to year; less dependency on whims of selected reviewers.*
5. *Review process is ambiguous.*
6. *Sometimes the proposal reviews are quite uneven and not very useful for improving the proposal. So the review process could be beefed up.*
7. *There seems to be no consistency in the review process. I received very good reviews one time and very bad reviews the next time (for the same grant). The instructions to reviewers who examined TDT grants appeared to be inconsistent with the instructions to the applicants. Reviewers' comments appeared as if they were using the ATP criteria for TDT grants.*
8. *While recognizing the problems connected with obtaining reviewers, the reviews are often inadequate. Most of those I have received were returned without a single comment and when comparing mine with those of other applicants, the basis of scoring by the reviewers in several categories was extremely non-uniform. During the last cycle, I submitted an application to expand my study to include other health science centers in Texas so that we could have access to more subjects and this was based on positive finds from the 2001 project. The reviewers for the 2001 project called the proposal "excellent," but the reviewers in the last cycle, without any specific comment, labeled the pre-proposal as essentially ridiculous, even though we were able with this proposal to provide data supporting the potential for efficacy.*
9. *Increased rigor of the review process in determining the quality proposals that will be funded. Provide option to pay for graduate student tuition in order to attract better qualified students.*
10. *Reviewing process of the proposals!!!!*
11. *Stronger, more thorough reviews of proposals.*
12. *The judging. My proposal was turned down on the basis of not enough support for graduate students when that was all it supported.*

13. *The grant selection process, although similar to many other grant selection processes with independent reviewers, does not seem to be designed to rank and select proposals based on their merit (both scientifically and financially) to the State of Texas. It also appears that smaller universities, even though many have very highly qualified researchers, do not seem to be treated fairly in the selection process. Many times grants are awarded based on "where you are from" rather than on what you have to offer.*
14. *The reviewers of ARP/ATP proposals are not qualified. The program needs better reviewers. The ATP program is important to Texas. However, the reviewing process can be described as a "crapshoot." The company reps that are often involved in the reviewing process don't look far enough into the future (eight-plus years). Often, this is not conducive to many types of research. The solution would be either to inform professors to write proposals that can be commercialized within two to three years or to get reviewer accustomed to looking eight to ten years down the road.*
15. *Reviews and scales should be modified. The ATP review board is bold and willing to take a chance—unlike [other] review boards. They have been very helpful to him.*
16. *Increase the rigor of review process in determining the quality of proposal that will be funded. Provide some option to pay for graduate student tuition, which could attract qualified bright students*
17. *I think the awards criteria are either misstated or not applied correctly. We had one faculty member from our department get an ATP funded who had not had a publication in ten years! How can that happen? Predictably, he returned most of the money and published nothing. I have seen awards given statewide in my discipline (chemistry) to people who were in no way competitive. In many ways, unless you fit a certain profile, it is more difficult to get money from this program than it is from NSF or NIH, where the review process is clearly less biased.*
18. *The review process is very uneven. In addition, fewer pre-proposals should get the green light so a higher percentage are funded*
19. *Make the funding process more transparent. It is not at all clear what the criteria are that will help an application get funded. The ATP review criteria [are] not transparent. PIs need to be informed about the review process so they can more clearly communicate with reviewers.*
20. *The review process should be more transparent and fair. Pre-proposal review does not permit serious evaluation of proposal merit. Feedback from review panel shows significant lack of understanding of the proposed work plan.*

<u>d. Allow PI to Rebut Review</u>

1. *I have the impression that on the last go-round, the review of my proposal did not take into account an excellent performance record. The PIs should be given an opportunity to rebut negative comments prior to the final decision on their applications.*
2. *Cancellation of programs after proposals have been written is very damaging (e.g., [ARP]). Too much emphasis on computer frills is a misdirection of effort. An*

opportunity for proposers to correct reviewers would be very wonderful, albeit difficult to administer.

e. Reviewers Lack Long-Term Focus

1. *The ATP program needs to be less concerned with industrial impact and more focused on supporting the best possible research. Good research, on its own terms, will find its way to industry. The apparently short-term focus of ATP/TDT discourages researchers from taking bigger gambles on longer-term ideas.*
2. *The evaluations often appear very biased to fundamental work that does not lead to economic development in the near term and they tend to be reviewed using criteria that favors science at the expense of generation of economic activities. It often reminds [me] of a "Texas research lottery."*
3. *More vision of the reviewers.*
4. *The reviewing is highly superficial and the awards go along with the funding patterns of previous years.*

f. Improve Reviewer Feedback

1. *The feedback from the reviewers really does not help improve the study.*
2. *More detailed feedback from reviewers.*
3. *Improve the review process. It seems sometimes arbitrary and the reviews do not go into much depth.*
4. *Provide more detailed feedback from the review process.*
5. *Provide more detailed feedback from reviewers at pre-proposal stage and for full proposals.*
6. *Improved review feedback so we know specific reasons for rankings below the funding level. The feedback we get is nearly useless as it now stands and forms the basis for calling the program the "Texas academic lottery" by Texas faculty participants. The funding decisions seem arbitrary with the scant feedback now provided.*
7. *More thorough reporting to applicant of evaluation of proposal.*

g. Other Comments

1. *I do not trust the reviewers or the selection process. The people who get ATPs at [name of university] are not necessarily our best faculty. I am turned off to the program completely.*
2. *Please improve the proposal review process.*
3. *Reading the proposals by the evaluators! We had proposals in the last two cycles rejected with a statement that what we propose cannot be done. In the body of each proposal we have given examples that the idea works, only more systems need to be investigated to get still better material properties.*

4. *The ATP program appears to fund only high-risk potentially high-return projects. There are a lot of projects that involve less risk with significant potential that could be funded. Why? Many of the high-risk high-potential projects are doomed to failure. Also, many times research projects of applied techniques to exiting processes have the potential of making significant improvement in the economic processing of chemicals and petroleum. Such research does not appear to have a high probability of being funded by the ATP.*
5. *The program is a waste of money because it was unfairly distributed.*
6. *The State may wish to think of core projects that have defined outcomes and timelines or may think of using these monies to support research infrastructure. I worry that the format of the grant and its review is [are] not terribly conducive to selecting the best research opportunities. The State has been very generous and its intentions are the best, but I do not know if the return has met these aspirations.*
7. *PI was disappointed in the ATP review/evaluation process because they didn't give him more funds to continue his research.*
8. *The focus of [ATP] has become too narrow on commercial potential only. Because of this, we (meaning all faculties in marine science) have not had a grant since the first two competitions. There are many natural resource problems that have to be addressed with State funds. ATP was the only source of this funding; now there is none.*
9. *ATP/ARP are excellent programs. Review process needs to be improved.*
10. *Getting funding from the ATP was a straightforward process back then. Now, things seem to have changed and gotten more complicated*

9.4 Principal Investigator Suggestions for Improvements in Grant Terms and Commercialization Support

HIGHLIGHTS

- Comments about potential changes in the ATP/TDT program focused on grant cycles and commercialization support.
- Comments exhibited considerable diversity as well as creativity.
- A selection of verbatim comments made by PIs merit consideration.

Principal Investigators provided numerous comments regarding potential changes and improvements in the ATP/TDT program. Specific comments on two aspects of the program, namely (a) grant terms and cycles and (b) commercialization support were recorded. Some of the comments have been incorporated into the assessment team's overall recommendations. Some of the comments are included only to present a fair balance of the information provided by PIs. Some of the comments are intriguing and merit consideration by the ACORP and staff as the program evolves.

Comments about Grant Terms and Cycles

1. *Allow some small percentage of the really top proposals to go for four years instead of two.*

2. *Make it longer (three years instead of two years). Projects required long-term perspectives.*

3. *In the past few years, I have been reviewing several major research programs in Singapore, The Netherlands, and the United Kingdom. All are mission oriented. All have a "blue sky" component. I suggest that the State of Texas initiate a program that addresses the need for out-of-the-box, blue sky projects.*

4. *Extend the funding time to at least three years, if cannot increase the funding.*

5. *Make the funding based upon high impact and high risk. Keep the funding per grant to less than $100K.*

6. *Allow for a higher flexibility in research and development personnel funded on projects. My suggestion about personnel relates to the relative weakness of [name of university] students to MIT, Stanford, and Berkeley students, making it relatively more important to use research scientists or postdocs or research faculty to a greater degree than in top engineering and science schools.*

7. *More projects in a broader range of research areas. Do not just target the so-called "hot" areas. Hot areas change with time and there are other agencies funding these areas. ATP should be funding "exploratory" areas that no other agency is funding because the thinking is that it is "risky." Some of the best ideas and inventions come in the areas that are not currently hot.*

8. *The ATP/TDT program should include a program supporting the technology development for the chemical industry. This high-technology industry provides high paying jobs for Texans and it represents one of the largest components of the Texas economic base.*

9. *The ATP program appears to fund only high-risk, potentially high-return projects. There are a lot of projects that involve less risk with significant potential that could be funded. Why? Many of the high-risk/high-potential projects are doomed to failure. Also, many times research projects of applied techniques to existing processes have the potential of making significant improvement in the economic processing of chemicals and petroleum. Such research does not appear to have a high probability of being funded by the ATP.*

10. *I think the intense focus on student employment by the program is not particularly helpful, and I would eliminate it as a criterion for receiving the grant.*

11. *The funds are insufficient for full-scale projects. Would be best used for innovative and/or risky research endeavors.*

12. *I think all good TDT proposals (which should be the majority of the proposals) should be funded because by the time someone gets to a TDT, they have done more than four years of work on the project and the bad ideas have essentially been eliminated by this time.*

13. *Fund more number of high risk- yield type of projects at lower funding level for one year duration to allow PI to test the hypothesis.*

14. *In general, there should be more capable reviewers who understand the technology path and better allocation of resources with follow-up support on an as-needed basis if the researcher is showing substantial progress.*

<u>Comments about Commercialization Support</u>

1. *Provide a panel of experts to support technology, marketing, and financial development that academia lacks. This team could be assigned based on project results, performance, etc. and at no extra cost to project.*

2. *Funding made available to pursue patents and licensing.*

3. *More emphasis on supporting start-up company activity.*

4. *Help PIs exert more leverage with Texas companies to contribute with matching funds/commitments; provide third year supplements to help bridge funding toward a major federal grant.*

5. *The difficulty I faced at [name of university] was that the focus of the program was short term. This hampered development of the technology. Also, the funding was not adequate to really do what was expected of us, namely, commercialize the outcome.*

6. *Make a follow-on funding program to extend funding of the most promising projects that need a bit more money to push it over the top.*

7. *Is the selection for full proposals based on technical merit, on economic potential for the State, or what? This whole process has been rather murky since its inception.*

8. *Extend the program to four years. Offer TDT automatically to ATP projects that develop a corporate partner. Emphasize economic development, not student training.*

9. *If technology transfer is a main goal, it might be useful to have more interaction/advertising (at a higher level than just our university) of results/projects.*

10. *Commercial development requires more non-degree seeking support, as it becomes more engineering and less science. Post-doc should be encouraged and undergraduate/MS involvement will be optimum, as little PhD training is appropriate for the TDT. PhD training is more appropriate for ATP and ARP topics. Industry involvement requires market demands and schedules as well as IP—no time/interest by industry for publications.*

11. *I would recommend creating a state-level mechanism to connect researchers with commercial sector.*

12. *More emphasis should be placed on student education and training. Some projects will be successful and generate additional monies and some will not. Nevertheless, the training of students ensures that the opportunity for new product development will occur at some point. Opportunities appear every day and only trained individuals can take advantage of these situations.*

13. *The evaluations often appear very biased to fundamental work which does not lead to economic development in the near term, and they tend to be reviewed using criteria that favor science at the expense of generation of economic activities.*

14. *Encourage industries to participate/contribute to the program. It seems basic scientists work alone.*
15. *ATP is most useful in creating projects to attract federal funding. It would be foolish to believe that the ATP program alone can bring technologies from the R&D stage to commercialization.*

16. *I have been impressed with how important this funding was for obtaining additional industrial funding and industrial partnerships toward commercialization of fundamental research results.*

17. *Size of awards needs to be greater in order to have significant impact on technology development/transfer.*

18. *Provide more funding such that those who have real commercialization ideas can get the resources needed to make the technology transition from the academic world into the private sector.*

19. *Assistance with industry partnership would be beneficial.*

20. *I think there is excessive emphasis on specific new products, intellectual property, and new companies formed. University research should not primarily be directed at setting up new business ventures, but at creating the foundation of knowledge that allows for the innovation throughout society. A university is not primarily an income-producing institution.*

21. *Personally, I would alter the program to be closer to the Ben Franklin program in Pennsylvania or the Edison program in Ohio. That is, this program should be more directly aimed at the applied research needed to directly and immediately affect the state economy. Too often, I feel, the funds have gone into the types of programs already funded by NSF and NIH.*

22. *Less emphasis on the start-up company being in Texas in the front end of evaluating the grant application and perhaps some incentive on the back end for this.*

23. *Increase visibility. Maybe find a better way to work closely together with investigators and Institutional Offices of Technology Ventures to find venture capital and pursue patents, etc., i.e., more support regarding intellectual property.*

24. *Give more time to develop products. Need help in identifying potential partners.*

<u>General Comments about the ATP/TDT Program</u>

1. *This is a wonderful program. It promotes graduate student and post-doctoral training and faculty research. An annual or biannual meeting of all recipients will enhance interaction and collaboration.*

2. *Overall, the ATP/TDT program is a fantastic program and something that attracts good faculty and graduate students to Texas. Many other states do not have such a program and the continuation of these programs is crucial. I feel that the commercial success of the technology developed in these projects may take a long time or sometimes may not be obvious to the PIs. Training students who can contribute to the workforce in Texas must continue to receive high importance.*

3. *Honestly, I think this is one of best managed research programs that I have ever seen. Little waste, no nonsense criteria, and well focused.*

4. *It is a valuable program that funds high-risk, technology-based projects. Funding for these types of initiatives is very difficult to get, and this program provides the opportunity for the development of academic research into technology.*

5. *I think the program is well managed and directed at a suitable mix of enhanced student education and commercialization of technologies developed within the state. The only enhancement I would suggest would be to increase the funding for the program. There are clearly highly competitive, commercially promising applications going unfunded today due to lack of sufficient funds.*

6. *The most important product from an ATP/TDT grant may not necessarily be patents or industry collaborations; after all, how many of the thousands of patents produced every year worldwide result in a commercial product? These grants are also an incomparable opportunity to train students in state-of-the-art technology, which otherwise they may not have access to. These grants also provide an opportunity for young scientists in Texas to continue their scientific careers and get enough preliminary data to apply later on for Federal funds. If one overlooks these benefits, one might be missing an important value of the ATP/TDT program.*

7. *Provide more funding. This is the best investment Texas can make to help train technologists in Texas and to bring high-tech companies to Texas.*

8. *It is an excellent program and the envy of other states.*

9.5 Programs in Other States

HIGHLIGHTS

- Various programs were identified in other states that may offer elements for inclusion in future ATP/TDT activities.
- Most attention is centered on support for prototypes and on addressing a number of existing gaps in the commercialization process, particularly involving start-up companies.

Various programs were identified in other states which may offer elements for inclusion in future ATP/TDT activities program reevaluations. Program performance data were not obtained, consequently, the descriptions are offered only as concepts for consideration and not as programs per se which should be adopted in their entirety or without detailed further investigation. The information below is primarily derived from program descriptions.

Proof of Concept Awards

1. Maryland's Technology Development Corporation has implemented the University Technology Development Fund ("the Fund"), a program to increase the number of early stage university technologies that are successfully commercialized. The Fund will allow universities to add value to early stage technologies through development prior to licensing to the private sector. Development projects will support early stage proof of concept testing, prototype development, feasibility demonstrations, and similar activities. Maryland allows up to $5,000 for initial patent expenses and pays 10 percent of total direct costs for university overhead.

Development projects supported by the fund will be managed by university technology commercialization offices and performed by university faculty and students. The primary focus is on technologies with high potential commercial value and substantial technical uncertainties that reduce the present value. To take advantage of the primary expertise of the university and its faculty and students who create new technologies, projects should address technical risk reduction rather than business plan development.

2. Earlier this year, the University of Colorado Technology Transfer Office (TTO) announced a new program in which university faculty or entrepreneurs working with faculty members could apply for $50,000-100,000 in "seed" investment funding.
The primary purpose of this funding is for short-term applied research and the creation of a prototype that may have significant market potential. A non-profit organization under contract to manage private equity for the university is managing the program. A critical role is performed by an investment advisory committee comprised of venture capitalists with experience in the scientific area being considered. As part of the evaluation process, applicants are given 20 minutes to present their proposal to this committee followed by a 10-minute question and answer session.

Increased Emphasis on Commercialization in University R&D

Georgia's Innovation Fund supports university-based R&D/commercialization projects. One of the categories, University/Industry Collaborations, is similar to ATP/TDT in that it provides support to investigate technologies, develop new technologies, or improve the products/processes of Georgia companies. They differ from ATP/TDT in several ways, however.

First, projects must address a market need or opportunity in one of three broad technology areas: (a) advanced communications, computing, and content; (b) bioscience; or (c) nanoscience and advanced materials. Although these areas are not tightly defined, bioscience, for instance, includes a broad range of biological, medical, and other life science technologies with applications in drugs/pharmaceuticals, agriculture, organic chemicals, medical device and instrument design/manufacturing, and bioscience research and testing, some ATP/TDT research areas would be excluded.

Second, awards are for a maximum of $100,000.

Third, Georgia-based industry partners must be companies already located in Georgia or actively pursuing a business location/relocation in Georgia.

Fourth, preference is given to projects with new or recently developed industry partners.

Fifth, half of the review and evaluation criteria are allocated for technical merit, including the experience and expertise of the project team, while half are devoted to commercialization potential, specifically (a) likelihood that effort will lead to commercial application and (b) commercial opportunity adequately researched and described.

Smaller Scale Research and Development Awards

The State of Washington's Technology Center (WTC) has a two-phase program of awards for university and nonprofit researchers teamed with a company partner located within the state. These competitively awarded projects begin with a Phase I project, supported by up to $40,000 of WTC funds. Successful completion and presentation of Phase I results are required for Phase II application. Phase II proposals may request up to $100,000 for a one-year project, which can be competitively renewed for an additional year—totaling $240,000 for the maximum awarded amount to any one project. Both phases require cash-matching by the company partner. Proposals for research projects in any technical area or industry are accepted. The proposal is submitted by the university or nonprofit research partner. Preference is given to research partner companies with fewer than 250 employees. About fifteen Phase I awards and eight Phase II awards are anticipated in 2005.

Use of Business Students To Facilitate Commercialization

With the dramatic increase in patents and intellectual property identified by universities over the past twenty years, the offices of technology transfer at universities have had difficulty in coping. Some technology transfer offices have turned to students in entrepreneurship programs to help them assess and develop discoveries by university researchers.

Teaming students with university researchers and a previous technology offers significant benefits for all parties. Students are able to focus on practical applications of their training and become involved in a venture that may lead to post-graduation opportunities. Researchers are able to tap into expertise they do not possess. Technology transfer offices have additional resources that can be devoted to technologies that otherwise may not be investigated or may not receive as much attention.

The McGuire Entrepreneurship Program at the University of Arizona has received national attention for one such effort. As of October 2004, twelve of the twenty teams currently in the McGuire program were working on business plans based on technology transfer. Last year, one of the groups and University of Arizona faculty developed a prototype retinal camera instrument and business plan and then sold them to a local business group in return for equity in the new company.

Bridging a Communication Gap Between Universities and Private Partners

A division of the Oklahoma Center for the Advancement of Science and Technology (OCAST), the Oklahoma Technology Commercialization Center (OTCC) performs several functions that introduce university researchers and their technologies to potential business and investor partners. University technologies must be approved for inclusion first, however, by a university representative and an OTCC director. Once approved, services are provided regarding IP protection, "quick look" (two-day) technology assessment, market assessment, development of a marketing plan, and business model and planning assistance. Also, principal investigators whose technologies are included in the program may participate in several networking activities, such as the three described below.

1. Meet the Scientist--Luncheons and breakfasts are jointly set up by the OTCC and the Greater Oklahoma City Chamber of Commerce to bring Oklahoma's research scientists, businesses, and capital community together. These events are scheduled about once per month. For about two hours, university scientists give presentations followed by a discussion with the attendees on the commercial development of the concepts being explored. Audiences are invited based on the technologies for each monthly session. When possible, prototypes are demonstrated.

2. Emerging Enterprise Evaluations (E^3)--Companies formed from university research and development are provided an opportunity to present their business plan to professional staff, mentors, service providers, investors, and others. The goal is to obtain early practical feedback on the plusses and minuses of the presented plan.

3. Southwest Capital Conference (SWCC)--The purpose of this annual conference is to bring together those seeking investment funds with venture and angel capital investors seeking technologies and companies in which to invest.

Addressing A Series of Gaps in the Commercialization Process

To support the development of technology prior to company formation, the Georgia Research Alliance created VentureLab, a suite of services for enhancing and accelerating the process of spinning new technology-based enterprises out of university research. These services are designed to address a number of problem areas or gaps between university research and development and entrance of a new company into an incubator. The services are interconnected, but not all would need to be adopted by the State of Texas or be implemented at the same time. The goals are to:

- Help universities identify laboratory discoveries that have commercial potential
- Guide faculty through the various stages of technology development so their ideas advance to the stage of company formation
- Provide earlier and increased awareness by the business and investment community of university commercialization opportunities.

VentureLab's strategy is to address the management, market, and technology risks associated with new venture formation and involve seasoned entrepreneurs in the formation of new companies.

Seed Grants—These grants are earmarked primarily for technology assessment, enabling schools to examine their research base and determine where technologies with commercial potential may exist and what kind of assistance is needed. Universities submit applications detailing how funds will be spent and the expected outcomes. Participating universities are expected to provide office space and infrastructure for the VentureLab program, and they are responsible for paying for VentureLab personnel.

VentureLab Fellows and Commercialization Catalysts--Faculty are teamed with experienced entrepreneurs and professional managers who serve as coaches and drive the commercialization process forward. Fellows are professional managers with a successful track record of new venture formation, expertise in new business formation, product development, and raising venture capital. Fellows also serve as initial chief executives for VentureLab companies. Commercialization catalysts function more as coaches, serving as business advisers and linking faculty with key resources in the community. In addition to entrepreneurial experience, catalysts possess technical knowledge in science and engineering. Both fellows and catalysts must be employees of the universities where their VentureLab program resides.

VentureLab commercialization grants—Two types of awards are available: (1) technology validation; (2) prototype creation.

> Technology validation--Awards of up to $50,000 are available to assess market demand for a product or service and determine interest from potential customers. The funding may be used to interact with prospective customers in order to validate market need for the products based on the technology, create preliminary product specifications, and formulate an initial business strategy.
>
> Prototype creation and Other Activities--Awards of up to $100,000 are available to help faculty develop a working prototype as well as develop a business plan, obtain seed capital, or pursue select federal grants (SBIR and STTR).

Fundamentally, Venture Lab is designed to serve as an advocate and a support for faculty wishing to commercialize research and development. VentureLab has also been designed to be flexible so it can be adapted to each university's needs, strengths, and industry connections. Based on the overall design and some early successes, VentureLab deserves consideration as one new activity for the ATP/TDT program, should new resources become available.

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Chapter 10: Potential Changes and Modifications

Based on detailed review and close analysis of collected information, the ATP program is fulfilling the original legislative goals and satisfying legislative intent. Economic impacts have been extensive, and they are ongoing. No strong imperative exists for changing the ATP/TDT program. Nevertheless, should policymakers desire to enhance benefits in future years, the following possible modifications may be considered. The first set of potential changes could be undertaken with existing program resources. The suggestions provided below are not in priority order.

Proposal Review Process

Award Criteria—If enhanced commercialization is desired, the review process should be more fully aligned with the desired outcome. Three changes would be: (1) to increase the weight in project funding decisions for the technology development and transfer plan in TDT proposals; (2) to consider the pros and cons of adding a new section or criterion about the likely economic benefits to the State of Texas, in effect, an economic justification for the proposed project; and (3) for ATP projects (not TDT) to reconsider the weight given to student involvement.[132]

Evaluators—Particularly with TDT proposals, consideration should be given to (1) having experts in commercialization review two sections (product, process, service, and technology development and transfer) of all proposals;[133] or (2) including a substantial number of evaluators with significant commercialization experience. This may include product development directors from large companies as well as chief technology officers from smaller companies who have first-hand experience with development. For TDT, fewer academicians and corporate R&D staff would serve as reviewers.

Principal Investigators—With TDT proposals, additional importance might be placed on their prior record in developing and transferring technology.[134]

[132] Although it will be impossible to address the variety across departments and universities in Texas, there are conflicts between educational and commercialization goals. In one notable example, a PI said graduate students in his department do not begin research until their third year, and yet he was evaluated on the number of students, rather than the number of post-docs, who would be involved, noting that the post-docs were more likely to contribute positively toward a commercialization outcome.

[133] Made under an appropriate confidentiality agreement.

[134] This criterion currently appears to be a maximum of 10 percent. Industry usually places a much higher importance on prior experience, oftentimes considering prior commercialization a key to success.

<u>Coordinating Board/Advisory Committee on Research Programs</u>

Goals for Future Commercialization—Although the ACORP and Coordinating Board do not control all aspects of this grant program, goals should be established on key outcome metrics. The federal Advanced Technology Program has established such goals, and it is reasonable that similar goals be developed for this Texas program. The first set of goals might be created for a target number of start-up companies and licenses from the 2005 funding cycle. Setting goals and monitoring progress thereafter may help to reinforce systematically the commercialization objective for ATP/TDT.

Monitoring of Specific Outcomes—Three potential concerns should be reviewed at a specific future time. First, some PIs stated that they view the ATP program as a source of research funds only and that they had no intention of ever commercializing. This was a small proportion, but PIs with such opinions should be excluded from receiving awards. The TDT program, in particular, should be considered the last research required before commercialization, not the next-to-last research. Second, the majority of start-ups have been in Texas. Yet one significant start-up and another very large start-up, arising in part from research done under ATP, are operating in other states. Some type of geographical restriction is not needed at this time, but the situation should be reviewed in the future. Third, except for a higher rate of start-ups by TDT awardees and the requirement for industrial partnership participation, not much difference was detected between the two types of awards. This may be due to the maturity of TDT awards compared to ATP—the TDT program has not existed for as many years. Or there may be other factors at work, such as outcomes for projects that were sequential (ARP-ATP-TDT or ATP-TDT), compared to those that were nonsequential (TDT). In several years this task should be performed to detect if there are differences between the outcomes of ATP and TDT projects.

Reporting Requirements—Follow-up data collection by ATP staff has occurred four years after projects were completed. Because of the time required for commercialization, a second follow-up data collection should occur after six or eight years. PIs should be expected to cooperate fully in providing non-proprietary business data for companies formed as a result of ATP/TDT projects. Otherwise, precise employment and salary data will not be collected.[135] Further, reporting should be extended to industrial partner impacts on cost savings, process

[135] Information in final reports is useful but fails to capture some crucial data. For instance, the assessment staff identified approximately 24 new start-up companies that were not in the HECB database of new companies. That was about 30 percent of the total. Some of these would have appeared in final reports, but others would have been unidentified. Methodical, periodic checking of companies cited by Pis is needed, as more than a dozen start-ups in the HECB database were erroneous companies that had been cited incorrectly by PIs.

improvements, and product enhancements.[136] A student survey or detailed student data collection effort in the future also should be undertaken to determine more precisely the role of projects in attracting them, aiding them in employment, and retaining them in the State of Texas after graduation. Although caution must be used in soliciting additional information, without these steps, the program's economic impacts are likely to be constantly underestimated.

Post-Project Initiatives

Fundamental Information on Commercialization and Technology Transfer—Most PIs and some technology transfer officials lack sophisticated understanding of commercialization principles beyond rudimentary patents and licensing basics. Many PIs have no experience in technology transfer. To provide additional knowledge, information should be offered to all successful award applicants, perhaps in the form of an easy-to-read primer outlining the fundamentals of technology transfer and the implications for the PI and her institution.

Supplemental Information For Commercialization—On a pilot project basis, commercialization support and guidance may be offered selectively to certain projects during the late stages of the research. Support could range from direct assistance in creating business plans and marketing strategies to brokering relationships for start-up company management. Many university technology transfer and licensing offices lack substantial human resources with expertise in the formation of new companies. In conjunction with the financing gap that exists in some regions in the state, commercialization assistance may be best provided under the auspices of the HECB. Contracting out a pilot project through a competitive bid, for example, is one possible approach. The success of the pilot program could determine the possibility of its evolution into a permanent feature of the program. An alternative, or possibly supplemental, approach would be a one- or two-day seminar on various topics of commercialization. Several of the sessions could be led by PIs who have encountered challenges and can describe their experiences in overcoming barriers.

New Program Initiatives

Should new resources be allocated to the ATP program, filling gaps in commercialization processes may be addressed. The new initiatives below are offered as examples of first steps.

Prototype Funding—A new, small grant program could provide resources solely for prototype development. Funds could be provided directly to all technology

[136] The reporting requirement should be entirely voluntary. Nonetheless, valuable information is likely to be collected if the request is made formally by the HECB staff and there is an explicit statement that all information provided will be maintained as confidential under the state's open records law.

transfer offices, or funds could be allocated by a review group on a different cycle than the ATP/TDT program cycle.

Large Grant Category—As a component of the normal grant cycle, a very limited number of larger awards, up to a maximum of $500,000 or $750,000, could be made. This will entice some more experienced PIs and industrial partners to apply, although the size of the awards still will be much smaller than federal ATP awards.

Internships and People Transfer Programs—To expose graduate students and some PIs to private sector R&D environments, a limited number of internships and semester-off programs could be undertaken. Funds could be earmarked for competitively awarded student externships associated with a project application. For PIs, "secondment," or the loan of an employee to another organization, in the British tradition, could be directly funded in cooperation with a cost-sharing industrial partner.

Company-directed R&D—Further study is recommended about the pros and cons of funding an experimental pilot similar to the federal Small Business Technology Transfer Program (STTR) program. Companies would apply in conjunction with university partners, with university funding awarded as a sub-contract.

Awareness and Knowledge of ATP/TDT—Given its size, the ATP/TDT enjoys a considerable reputation with Texas scientists and university offices of sponsored research. Beyond those populations, however, familiarity with ATP is scant, particularly among venture capitalists, major industrial partners, and resource providers such as incubators and economic development directors. By raising awareness of the ATP, its effectiveness could be enhanced. The adoption of a public relations strategy and the dedication of resources to effect it would increase awareness among key stakeholders.

THE ATP/TDT PROGRAM MISSION

The potential changes and modifications cited above will maintain the overall integrity of the ATP/TDT program while sharpening its focus to improve commercialization further in coming years. If a reconsideration of policy leads to the conclusion that near-term, direct economic outcomes are the overriding goal, then different approaches (product development or grants to businesses) should be established. As it stands, the ATP/TDT program targets applied research and development, workforce development, and commercialization.[137]

[137] Our sample of industrial partners indicates that all of these goals are important. The conduct of R&D that otherwise would not occur, intelligence about market conditions, and particularly the ability to attract trained graduates are very important goals. See Chapter 5, section 3 for further information.

In summary, the ATP program is fulfilling the original legislative goals, and its impacts to date have far surpassed the state's investments.

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Appendices

APPENDIX A: Survey Instrument

(Note: The spacing has been modified from the original online version.)

ATP/TDT Survey

Thank you for participating in this survey of ATP/TDT grant recipients. If you have served as the Principal Investigator for multiple projects, you will be prompted to fill out questions for each project. **It is vitally important that we have your responses for each of your projects.**

We ask for your patience if some questions appear to duplicate information you previously have supplied to the State of Texas Higher Education Coordinating Board; the research team is independently analyzing the impacts of the grant program using its own methodology, whenever possible.

If you have any questions about completing the survey, please contact Leah Campbell via email: leah.campbell@mccombs.utexas.edu or by phone at (512) 232-7154.

1. **If you are not the original recipient of this survey but are filling it out on their behalf, please enter your contact information here.**

   This information is so that we may respond to any questions you have regarding this survey.

2. **For what type of project(s) have you served as Principal Investigator?**

   Please check all that apply.

   ○ ATP
   ○ TDT

3. **Please select the start date(s) for your projects.**

   Please check all that apply. If you are unsure of a project date, please locate your project via the ATP website at ATP Award Search (http://www.arpatp.com/visitors/AwardSearch.htm).

   ○ 1988 (awarded in 1987 competition)
   ○ 1990 (awarded in 1989 competition)
   ○ 1992 (awarded in 1991 competition)
   ○ 1994 (awarded in 1993 competition)
   ○ 1996 (awarded in 1995 competition)
   ○ 1998 (awarded in 1997 competition)

○ 2000 (awarded in 1999 competition)
○ 2002 (awarded in 2001 competition)

DIRECTIONS: Please answer questions 5 -26 for each ATP/TDT project for which you acted as PI. If you have had multiple ATP/TDT projects please answer 5-26 for each project.

4. Select the field in which your project occurred.

If you are unsure, please locate your project via the ATP website at ATP Award Search.

○ Aerospace
○ Agriculture / Aquaculture / Agricultural Biotechnology
○ Biomedicine
○ Biotechnology
○ Computer and Information Engineering / Electrical Engineering
○ Energy
○ Environmental Science and Engineering / Recycling and Water Resources
○ Manufacturing Technology
○ Marine Technology
○ Materials Technology
○ Medical Biotechnology
○ Microelectronics
○ Telecommunication
○ Transportation

5. Please provide the project title or the project number.

6. How many students worked on your project?

Please include only students who were paid through project funds.

	1-3	4-9	10-19	20 or more
Post-Doctoral	○	○	○	○
Doctoral	○	○	○	○
Masters	○	○	○	○
Undergraduate	○	○	○	○

7. **How many *graduate* students were employed full time for more than six months in jobs located in Texas as a result of their work on your project?**

   Please list number of students by sector of employment. If you do not know, enter zero (0).

   University / Academic positions ______
   Business / Government positions ______

8. **How many *undergraduate* students were employed full time for more than six months in jobs located in Texas as a result of their work on your project?**

   Please list number of students by sector of employment. If you do not know, enter zero (0).

   University / Academic positions ______
   Business / Government positions ______

9. **Please cite any marketable skills or competencies acquired by students who worked on your project.**

10. **At what stage of the technology or product development cycle is your project?**

    Please select only one.

    ○ No product development is anticipated
    ○ Two or more years of additional R&D are required
    ○ One more year of R&D is required
    ○ Prototype process development is occurring now
    ○ A satisfactory prototype process have been developed
    ○ The project is beyond the prototype process stage
    ○ Serious planning for commercialization is underway
    ○ Commercialization has begun

11. Which of the following resulted specifically from your project?

Please list the approximate number. If the question does not apply, skip it and move on to the next question.

Inventions disclosed ______
Patents filed ______
Patents issued ______
Patents abandoned ______
Products introduced to market ______
Copyrights registered ______
Total number of trademarks and all other pieces of intellectual property (trade secrets, know how, technical data, etc) for which resources were dedicated to protect ______
Non-funded collaborations with other academic or industry alliances where a minimum of one-month of researcher's time is spent ______
Licenses granted, total ______
Number of licenses granted to large companies (over 500 employees) ______
Number of licenses granted to small companies (under 500 employees) ______
Number of licenses granted to start-up companies ______
Number of licenses granted to companies in which the your university holds stock or otherwise has equity share ______
Options executed, total ______
Number of licenses currently returning royalty or non-royalty payments ______
Number of licensees living or working in Texas ______
Total amount (dollars) of license gross revenue (total royalty and non-royalty payments) earned by project to date ______
New major industrial programs that originated from this project ______
Follow-on research funds (dollars), Total ______
Follow-on research funds (dollars), Federal ______
Follow-on research funds (dollars), Industrial ______
Follow-on research funds (dollars), State, Foundation, International ______

12. How many companies were formed as a result of this project?

Please include only those companies formed in Texas with at least $5,000 in start-up capital investment.

○ None
○ One
○ Two
○ Three or more

DIRECTIONS: If one company was formed, please answer Questions 13-19. If two or more companies were formed, you will be contacted directly and may skip ahead

13. Date of company formation (approximate month and year).

14. Sales Revenue

Total sales revenue to date (dollars) _____
Number of funding events of seed capital, angel investment, or venture capital of more than $25,000 to commercialize process/product _____

15. Has the company made an initial public offering (IPO)?

○ Yes
○ No

16. If "yes", what is the name of company?

17. What is/was the date of the IPO?

18. Please provide the average number of jobs per year at the company.

○ None
○ 1-3
○ 4-20
○ 21-50
○ 51-99
○ 100-199
○ 200 or more

19. Is this company still active (continuing to pay employee salaries or continuing to fund a marketing budget of at least $2,500 per year)?

○ Yes
○ No

20. To the best of your knowledge, has your project led to the adoption by an industry partner of a new process (or improvement of an existing process), or, produced cost savings, cost avoidance or a product enhancement?

○ Yes
○ No

21. If "yes", please provide an estimate of its economic benefit (dollars) to the company/companies which have utilized it.

If you cannot estimate please enter zero (0).

22. If you would prefer to provide a referral, please identify whom we should contact and a phone number or email for this person.

23. Is/was your industry sponsor (either the parent corporation or a subsidiary) located in Texas?

○ Yes
○ No

24. Indicate if you agree or disagree with the following statements.

Strongly Agree **Neutral** **Strongly Disagree** **Not Applicable** **Don't Know**

(A) The ATP/TDT award provided enhanced credibility for subsequent research application(s) to federal agencies, industrial sponsors, or investors.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree **Neutral** **Strongly Disagree** **Not Applicable** **Don't Know**

(B) Without the ATP/TDT award, I would have pursued development of the technology at about the same level of effort and with the same ultimate goal.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree **Neutral** **Strongly Disagree** **Not Applicable** **Don't Know**

(C) Resources will be dedicated to protecting the intellectual property (patents, copyrights, trademarks, know how, technical data, etc) developed in this project.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree			Neutral			Strongly Disagree	Not Applicable	Don't Know
(D) I have reason to expect that rights to the intellectual property developed as a result of this project will be licensed in the future.								
○	○	○	○	○	○	○	○	○

Strongly Agree			Neutral			Strongly Disagree	Not Applicable	Don't Know
(E) As a result of the funding received under the Advanced Technology Program the commercialization of technology was accelerated.								
○	○	○	○	○	○	○	○	○

25. What needs, if any, does your industry partnership have before the desired commercial potential of your research can be achieved?

Please check all that apply.

○ Will need financial assistance
○ Will need manufacturing or production assistance
○ Will need marketing assistance
○ Will need further R&D resources
○ Do not have any needs

26. Have you encountered any problems or impediments with your laborators or industry sponsors, or in working with your university, that have prevented your research from achieving its desired potential?

○ Yes
○ No

27. If "yes", what was/is the problem, and what are possible solutions?

DIRECTIONS: This is the end of the questions which are specific to each project you participated in. Please answer the remaining questions as they pertain to <u>all</u> of your projects.

28. Indicate how important you find the following statements.

Very Important			Moderately Important			Not Important	Don't Know
(A) How important are the ATP/TDT grant programs in ATTRACTING outstanding *graduate* students to your institution?							
○	○	○	○	○	○	○	○

Very Important　　Moderately Important　　Not Important　　Don't Know

(B) How important are the ATP/TDT grant programs in ATTRACTING outstanding *faculty* to your institution.

○ ○ ○ ○ ○ ○ ○ ○

29. Indicate if you agree or disagree with the following statements.

Strongly Agree　　Neutral　　Strongly Disagree　　Not Applicable　　Don't Know

(A) Educated students are the most important product of the ATP/TDT programs.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree　　Neutral　　Strongly Disagree　　Not Applicable　　Don't Know

(B) ATP/TDT programs contribute significantly to producing graduates properly educated for their intended job markets and future career tracks.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree　　Neutral　　Strongly Disagree　　Not Applicable　　Don't Know

(C) The ATP award enabled me to secure additional federal or foundation funding, which I likely would not have obtained otherwise.

○ ○ ○ ○ ○ ○ ○ ○ ○

Strongly Agree　　Neutral　　Strongly Disagree　　Not Applicable　　Don't Know

(D) The TDT award enabled me to secure additional industrial funding, which I likely would not have obtained otherwise.

○ ○ ○ ○ ○ ○ ○ ○ ○

30. What specific economic benefits (for the State of Texas, your university, or your local community), not referred to in a previous question, can you cite which have resulted from your project(s)?

31. Please cite any educational and/or entrepreneurial program(s) on campus that were supported or impacted by your project(s)?

32. What, if anything, should be changed to improve the ATP/TDT program, and why?

We thank you very much for your time and effort in completing this survey.

If you wish to provide additional substantive comments or to communicate other relevant information beyond your responses, it would be very beneficial if you sent an email to: ATP@mccombs.utexas.edu.

Please note that if you are a TDT Principal Investigator, someone from the research team may be contacting you by telephone in the next several months.

APPENDIX B: Letters/emails to Principal Investigators

Email 1: Initial Introduction and Request for Survey Participation
Date: March 16, 2004

From: ATP@mccombs.utexas.edu
Subject: Message from Linda Domelsmith: Survey of ATP/TDT Programs

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Dear {insert Principal Investigator's name},

I am writing to ask you to participate in a comprehensive impact assessment of the achievements and accomplishments of the State of Texas' Advanced Technology Program (ATP) and Technology Development and Transfer Program (TDT). The study is being conducted by a team led by Dr. James Jarrett of the McCombs School of Business at The University of Texas at Austin.

Studies of the impact of the ATP and TDT on the state were suggested by a panel of experts appointed by the Coordinating Board to evaluate the Programs (http://www.thecb.state.tx.us/reports/pdf/0586.pdf). The panel's report stated that the ATP and TDT are "not well known by Texas industry nor by Texas citizens." The report went on to say that "It is important that Texans understand the very positive impact and contribution of these programs to the state, its universities, and its business environment." Especially during times of severe resource constraints it is essential that a program's impacts be identified and communicated to policymakers.

Our records indicate that you have been awarded one or more ATP or TDT grants. A key element in which you are being asked to participate is a short survey of all ATP/TDT principal investigators. Completing this web-based survey should only take about ten minutes of your time per research project. Your answers will be strictly confidential—no principal investigators will be individually identified, no project-level information will be cited, and only aggregated data and information will appear in the public report.

To complete the survey, please click on the following link: {insert user-specific link to survey}

We would like to have all surveys completed by March 31. Your timely response will help ensure that ATP and TDT achievements and benefits are documented.

Thank you in advance for your assistance and cooperation.

Dr. Linda N. Domelsmith
Director of Research
Finance, Campus Planning and Research Division
Texas Higher Education Coordinating Board

Email 2: Reminder Email to Non-Respondents
Date: March 30, 2004.

From: ATP@mccombs.utexas.edu
Subject: Your ATP/TDT Project(s)

Dear {insert Principal Investigator's name},

Several weeks ago we contacted you regarding a short survey about projects funded by the State of Texas' Advanced Technology Program (ATP) and Technology Development and Transfer Program (TDT). According to our records, we have yet to receive any information regarding your project(s). We kindly request that you complete the web-based survey before April 8.

The survey is available at: {insert user-specific link to survey}

Your response will ensure that outcomes for projects in your research field are adequately represented in future program funding decisions. Additionally, your timely response will ensure that we do not bother you with further emails in coming weeks.

Thank you in advance for your participation.

Leah Campbell
Researcher
McCombs School of Business

Email 3: Initial Introduction and Request for Survey Participation for Principal Investigators with Incorrect Email Addresses in March 16 Email

Date: March 30, 2004

From: ATP@mccombs.utexas.edu
Subject: Message from Linda Domelsmith: Survey of ATP/TDT Programs

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Dear {insert Principal Investigator's name},

I am writing to ask you to participate in a comprehensive impact assessment of the achievements and accomplishments of the State of Texas' Advanced Technology Program (ATP) and Technology Development and Transfer Program (TDT). The study is being conducted by a team led by Dr. James Jarrett of the McCombs School of Business at The University of Texas at Austin.

Studies of the impact of the ATP and TDT on the state were suggested by a panel of experts appointed by the Coordinating Board to evaluate the Programs (http://www.thecb.state.tx.us/reports/pdf/0586.pdf). The panel's report stated that the ATP and TDT are "not well known by Texas industry nor by Texas citizens." The report went on to say that "It is important that Texans understand the very positive impact and contribution of these programs to the state, its universities, and its business environment." Especially during times of severe resource constraints it is essential that a program's impacts be identified and communicated to policymakers.

Our records indicate that you have been awarded one or more ATP or TDT grants. A key element in which you are being asked to participate is a short survey of all ATP/TDT principal investigators. Completing this web-based survey should only take about ten minutes of your time per research project. Your answers will be strictly confidential—no principal investigators will be individually identified, no project-level information will be cited, and only aggregated data and information will appear in the public report.

To complete the survey, please click on the following link: {insert user-specific link to survey}

We would like to have all surveys completed by April 12. Your timely response will help ensure that ATP and TDT achievements and benefits are documented.

Thank you in advance for your assistance and cooperation.

Dr. Linda N. Domelsmith
Director of Research
Finance, Campus Planning and Research Division
Texas Higher Education Coordinating Board

Email 4: Final Email and Reminder to Non-Respondent Principal Investigators

Date: April 22, 2004

From: ATP@mccombs.utexas.edu
Subject: Message from Linda Domelsmith: Survey of ATP/TDT Programs

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Dear {insert Principal Investigator's name},

On two occasions over the past five weeks you were asked to respond to a short survey about projects funded by the State of Texas' Advanced Technology Program (ATP) and Technology Development and Transfer Program (TDT). We have yet to receive information regarding your project(s). Please complete the web-based email survey before April 30.

You may respond only to questions which you can answer from memory and skip those which require searching project records. Please note, in order to complete the survey online you will be prompted to answer all questions with a red asterisk (*), however, these questions should be able to be answered from memory.

To connect to the survey please use the following link: {insert user-specific link to survey}

If you have any problems with the website, we can provide you a copy of the survey via email. Your response will ensure that outcomes from your project and projects in your research field are adequately represented in future program funding decisions.

If you have any questions or feel you have received this email in error please feel free to contact me directly.

Thank you.

Leah Campbell
Research Assistant
McCombs School of Business

APPENDIX C: Certified Capital Companies Program (CAPCO)

The 78th legislature passed into law HB 2425 which, in part, provided for the creation of state-certified venture capital companies called CAPCOs. CAPCOs are state-regulated, privately owned and operated venture capital entities that invest funds in small and emerging businesses located in Texas. The state provides economic development tax credits to investors in a CAPCO. The CAPCO program will make available a total of $200 million of venture capital for small businesses beginning in 2005. These funds will be invested at the maximum rate of $50 million per year.

In order to receive an investment from a CAPCO, a business:

- Must have been denied traditional bank financing;
- Must be headquartered in Texas with its principal business operations located within the state;
- Must employ fewer than 100 people with at least 80% located in state and must pay 80% of its payroll in state;
- Must be primarily engaged in manufacturing, processing, assembling products; research and development and services; and
- Must not be primarily engaged in the business of retail sales, real estate development, insurance, banking or lending or the professional services provided by accountants, physicians or attorneys.

Every CAPCO must invest at least 50% of the capital it invests within the first 5 years in "early stage businesses." An early stage business is classified as any company that is engaged in initial product or prototype development, has less than $2 million in gross revenue or has been incorporated less than 2 years.

CAPCOs must invest 30% of the capital it invests in the first 5 years in "strategic investment businesses." A strategic investment business is classified as any company that meets the characteristics of a "qualified investment" and is located in a strategic investment area, typically a disadvantaged area.

(The above material was drawn from http://www.texascapital.org/about/capco.php and draft rules from the Comptroller of Public Accounts.)

New Businesses From ATP/TDT Awards

Round	PI F. Name	PI L. Name	Institution	Project #	Type	New Company Name
Active Companies						
1987	Jonathan	Sessler	UT	xxxxxx-1581-1987	ARP, ATP	Pharmacyclics
1989	William	McDavid	UT-SA	003659-0015-1989	ATP	Radworks Corp
1991	Delbert	Tesar	UT	000512-0267-1991	ATP	ARM Automation
1991	Clifford	Fedler	TTU	003644-0064-1991	ATP	Global Scientific
1995	Paul	Ho	UT	003658-0205-1995	TDT	Mestronix
1995	Ted	Reid	TTU	010674-0065-1995	TDT	Selenium Technologies
1995	Ted	Reid	TTU	010674-0065-1995	TDT	Selenium Ltd
1997	Robert	Eberhart	UTSWMC-D	010019-0047-1997	ATP	TissueGen
1997	Alexander	Oraevsky	UTMB	004952-0054-1997	ATP	LaserSonix Technologies -> Fairway Medical Technologies Inc.
1997	John	McGlone	TTU	010674-0059-1997	ATP	Eclipse Bioscience
1997	Mark	Weichold	TEES	000512-0112-1997	TDT	Stellar Display Corporation
1999	Robert	Flake	UT	003658-0491-1999	ATP	Bluefin Technologies, Inc.
1999	Rodger	Walser	UT	003658-0849-1999	TDT	MetaMaterials, LLC
1999	John	Buynak	SMU	003613-0003-1999	ATP	AlamX LLC
1999	David	Starikov	UH	003652-0228-1999	ATP	Integrated Micro Sensors, Inc.
1999	Thomas	Milner	UT	003658-0359-1999	ATP	AdaptiVision
2001	Ron	Matthews	UT	003658-0588-2001	ATP	RSET, Inc.
2001	David	Bourell	UT	003658-0590-2001	TDT	Advanced Laser Materials, LLC
2001	Stanley	Roux	UT	003658-0571-2001	ATP	Entercel
2001	Robert	Schwartz	BCM	004949-0104-2001	ATP	Kardia Therapeutics
2001	Brian	Korgel	UT	003658-0003-2001	ATP	Innovalight
2001	Mehrdad	Ehsani	TEES	000512-0285-2001	TDT	Electromotion, Inc.
2001	John	Alderete	UTHSC-SA	003659-0006-2001	TDT	Xenotope Diagnostics, Inc.
2001	Benito	Fernandez	UT	003658-0022-2001	ATP	Hierophant Systems, Inc.
2001	K.T.	Hartwig	TAMU	000512-0338-2001	TDT	Shear Form
Sold Or Acquired						
1987	Kathleen	Hennessey	TTU	003644-1451-1987	ATP	ISOA Inc. -> Rudolph Technologiers
1989	Bernard	Pettitt	UH	003652-0233-1989	ATP	Triplex
1989	M. Ray	Mercer	TEES	003658-0541-1989	ATP	PSI Systems
1989	Louis	Smith	BCOM	004949-0108-1989	ATP	Perceptive Scientific Instruments
1989	Bradley	McIntire	UTMDACC	003604-0048-1989	ATP	Endogen
1989	Anthony	Gorry	BCOM	004949-0014-1989	ATP	The Forefront Group
1991	Don	Johnson	Rice	000512-0267-1991	ATP	Modulus Technologies
1991	John	Mills	UT-Arlington	003656-0114-1991	ATP	Global Integration
1991	Jim	Klostergaard	UTMDACC	003657-0098-1991	ATP	Argus Pharmaceuticals
1993	Earnest	Gloyna	UT	003658-0354-1993	ATP	Eco Waste Technologies
1997	Eric	Anslyn	UT	003658-0042-1997	ATP	Labnetics

Defunct						
1987	William	Stavinoha	UTHSC-SA	003659-2276-1987	ATP	Organotech
1987	Henry	Taylor	TEES	000512-4434-1987	ATP	FFPI Industries -> Fiber Dynamics
1987	Joel	Barlow	UT	003658-3544-1987	ATP	JemPac International Corp
1987	Edmund	Lusas	TEES	000512-2129-1987	ATP	Sunlean Foods Co.
1987	Robert	Roberts	BCOM	004949-3739-1987	ATP	Xenos medical systems
1987	Jose	Bencomo	UTMDACC	003657-1533-1987	ATP	Zerbec, Inc.
1989	Ronald	Estabrook	UTSWMC-D	003658-0201-1989	ATP	Oxygene/Dallas
1991	F. L.	Lewis	UT-Arlington	003656-0008-1991	ATP	Control Development Inc.
1993	David	Kung	UT-Arlington	003656-0097-1993	ATP	Actrya Systems
1993	Earnest	Gloyna	UT	003658-0354-1993	ATP	Hydro Processing
1993	J. Clifford	Waldrep	BCOM	004949-0013-1993	TDT	Therapeutics 2000, Inc.
1995	Behrooz	Shirazi	UT-Arlington	003656-0087-1995	ATP	Prism Parallel Technologies, Inc
1995	James	Smith	BCOM	004949-0058-1995	ATP	Sennes Drug Innovations, Inc.
1997	Richard	Barr	SMU	003613-0023-1997	ATP	TelOptica
1999	John	Keto	UT	003658-0362-1999	TDT	Quanta Lux Corporation
1999	Mukul	Sharma	UT	003658-0750-1999	ATP	Synergy Computing Inc.
2001	Gerald	Morrison	TEES	000512-0294-2001	TDT	Flowline Meters, Inc.
2001	Stanley	Roux	UT	003658-0571-2001	TDT	Texagen
2001	Peter	Nordlander	RICE	003604-0075-2001	ATP	Nanospectra, LLC
Direct Result of ATP (Probably Defunct)						
1987	Jonathan	Uhr	UTSWMC-D	010019-4269-1987	ATP	Inland Laboratories
1987	Jonathan	Uhr	UTSWMC-D	010019-4269-1987	ATP	TexStar Monoclonals -> Dallas BioMedical Corp.
1991	John	McIntyre	TAMU	010366-0016-1991	ATP	(HECB reported as John McIntyre Group)
1993	Willy	Zwaenepoel	Rice	003604-0012-1993	TDT	Parallel Tools, LLC
1997	Robert	Schwartz	BCOM	004949-0022-1997	ATP	Applied Veterinary Systems, Inc.
Probably Direct Result of ATP (Active)						
2001	Henryk	Temkin	TTU	003644-0172-2001	TDT	Multipass Corporation
Probably Direct Result of ATP (Defunct)						
1997	David	Baskin	BCOM	004949-0054-1997	ATP	Molecular Therapeutics
Probably from ATP, but only a portion (Active)						
1991	Carl	Collins	UT-Dallas	009741-0011-1991	ATP	SI Diamond Technology, Inc. -> Nano Proprietary Inc.
Probably not a result of ATP, but % attributable (Active)						
1993	G. P.	Peterson	TEES	000512-0039-1993	TDT	Merix Corporation (License to Established Companies)

Unknown ATP attribution, Sold or Acquired

1989	Kenneth	Beattie	BCOM	004949-0006-1989	ATP	Genosys Biotech

Uncertain

2001	Josef	Kas	UT	003658-0238-2001	TDT	Evacyte Corp.

Case Studies (Several Acquired)

1987	James	Wild	TAMU	000517-3295-1987	ATP	Reactive Surfaces Ltd
1987	Joseph	Beaman	UT	003658-4380-1987	ATP	DTM Corp. -> 3D Systems
1989	Darrell	Carney	UT-Dallas	004952-0028-1989	ATP	Chrysalis Bio-Technology
1991	Alexandre	Freundlich	UH	003652-0243-1991	ATP	International Stellar Technologies
1991	Manfred	Fink	UT	003658-0136-1991	ATP	Omedtech
1991	Guenter	Gross	UNT	003594-0062-1991	ATP	ANND -> CNNS
1993	Karan	Harbison	UT-Arlington	003656-0112-1993	ATP	Scen Pro
1995	Sarah	Highlander	BCOM	004949-0037-1995	ATP	ProKaryon
1995	Lenard	Lichtenberger	UTHSC-H	011618-0122-1995	ATP	Plx Pharma
1997	Mark	Holtzapple	TEES	000512-0184-1997	ATP	Terrabon
1997	Eric	Olson	UTSWMC-D	010019-0078-1997	ATP	Mantex Biotech
1997	Michael	Manry	UT-Arlington	003656-0063-1997	ATP	Neural Decision Lab
1997	Stephen	Johnston	UTSWMC-D	010019-0065-1997	TDT	Elliance Company -> Macrogenics
1999	Gary	Evans	SMU	003613-0023-1999	ATP	Photodigm
1999	Richard E.	Smalley	Rice	003604-0055-1999	ATP	Carbon Nanotechnologies, Inc.
1999	Bert	O'Malley	BCOM	004949-0078-1999	ATP	Vector Therapeutics -> Gene Medicine -> Valentis
2001	Enrique	Barrera	Rice	003604-0039-2001	TDT	Nanoridge

Errors

1989	David	Cocke	LU	003581-0023-1989	ATP	Southern Clay Products
1993	John	Papaconstantinou	UTMB-G	004952-0024-1993	TDT	Hyalose
1993	Roy	Weinstein	UH	003652-0016-1993	ATP	SuperConductive Components (licensing)
1993	Ben	Streetman	UT	003658-0024-1993	ATP	PicoLight, Inc.
1993	Beverly	Clement		010366-0153-1993	ATP	Vicam (licensing agreement)
1989	Thomas	Runge	UTHSC-SA	003659-0037-1989	ATP	Medisan Pharmaceuticals
1989	Susan	Berget	BCOM	004949-0086-1989	ATP	EMC Tech
1987	David	Carnes	UT-SA	003659-1156-1987	ATP	Brassler USA Inc.
1995	John	Hazle		003657-0109-1997	ATP	Sigmages->Teralogic -> Oak Technologies (2002) -> Zoran Inc. (Aug 11, 2003)
1993	Khosrow	Behbehani	UT-A	003656-0122-1993	TDT	Respironics.com
1989	L. Gary	Adams	TAMU	000517-0045-1989	ATP	Diagnostics and Biologics
1995	Hamid	Toliyat	TEES	000512-0083-1995	ATP	? - PI's company
1999	Raymond	Budde	UTMDACC	003657-0069-1999	ATP	Signase, Inc. (Neil Douglas)
1997	Phillip	Lee	UTMB	004952-0079-1997	TDT	Poseidon, Inc.
1999	Pen-Chu	Chou	UH	003652-0139-1999	TDT	Metal Oxide Technologies, Inc.
1989	Delbert	Tesar	UT	003658-0156-1989	ATP	Cybo Robots

APPENDIX E: TheraSense

Blood glucose concentration measurement for diabetics is performed approximately 6 billion times each year, apparently the most frequently performed chemical test in the world. Several technologies originating from two ARP awards have led to development of a small, wireless sensor-based continuous glucose monitoring system which will revolutionize daily activities for diabetics. One part of the device reduces the pain of monitoring blood glucose by minimizing dramatically the required blood sample size. A second breakthrough uses a wired enzyme technology that transmits results to a small receiver carried by the diabetic. This process allows the user to know his/her glucose levels and receive a warning if those levels approach specified warning boundaries. The primary technologies originated from the ARP-supported research by Professor Adam Heller of the University of Texas at Austin. In 1996 Professor Heller and his son founded TheraSense to market glucose monitoring devices. In spring 2004, TheraSense was sold to Abbott Laboratories for $1.2 billion.