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Evaluation of Iowa State University's Center for Advanced Technology Development: Executive Summary

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Introduction[*]

The Center for Advanced Technology Development (CATD) was established in 1987 at Iowa State University (ISU) with funds from the U.S. Department of Commerce. CATD is part of a larger technology transfer mechanism at Iowa State, the Institute for Physical Research and Technology (IPRT), a consortium of research, technology development, and technology transfer organizations in the physical sciences and engineering.

This report is an executive summary of an independent evaluation of CATD. After overviews of CATD and the full evaluation study, following sections consider the costs and benefits associated with the center's programs, results from case studies, benchmark comparisons with other programs, and implications for public policy and the management of industry-university collaborative research.

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Overview of CATD

CATD seeks to bridge two gaps in the innovation process: between the research results of the university and the commercial market; and a company's problems and the expertise resident at the university.

To address the first gap, CATD funds research intended to demonstrate proof-of-concept and develop advanced prototypes. To address the second, CATD can match funds provided by industry to address industrial problems.

CATD has two operating units, the Office of Contract Research (OCR) and the Office of Technology Commercialization (OTC), whose activities are directed toward achieving the above goals. To oversimplify somewhat, OCR's goal is to help solve industrial problems using university resources, thereby bringing research contracts into ISU. OTC's goal is to commercialize university technology created by IPRT scientists and ISU faculty affiliated with the IPRT.

OCR signs contracts for diagnosis and problem-solving at companies. Clients are primarily small and medium enterprises (SME's).[1] Work is sometimes done on a cost-shared basis, with companies able to use in-kind contributions for cost sharing. Cost sharing ratios vary. Contracts include a licensing clause that gives the client first option to an exclusive license to any patented technology generated within the project.

OTC seeks to match ISU technology to client company needs and provide research support to fine-tune the technology. Companies often fund the final states of research. All projects are intended to result in a license to the company, and contracting companies are asked to take an option to license the technology. The funding for OTC-related projects is intended to reduce the risk for the commercializing firm.

OCR projects are intended to generate contract research support to the university, not to generate royalty income. All OCR projects involve ISU academic faculty or IPRT scientists. Projects are intended to generate research income for the university and solve problems for the company, or develop new products where ideas originate with the company

OTC supports 10-20 new projects each year through an RFP process using Department of Commerce and State of Iowa funds. The RFP's are directed primarily toward ISU faculty and Ames Lab; it is intended as an idea-generating process.

Commercialization projects supported by OTC have been in place since 1988, when CATD was founded, whereas OCR projects were initiated in 1990. During the early years when lump sum funding was available from DOC, until about 1992, CATD supported larger projects, projects in the $100,000 and up range. These projects also tended to have a longer time frame (several years) than more recent projects, which are designed to produce results in less than a year. As funding sources and requirements changed, the number of new projects funded each year has remained in the range of 15-20, but project size has dropped considerably. In addition, projects supported in the last several years increasingly have involved industry cost-sharing. CATD expects the time span from invention disclosure to product to be about 7 - 12 years. In CATD's view, the "real" technology transfer occurs *after* a license has been negotiated. Transfer processes and outcomes include consulting, hiring of students, conferences, and research contracts.

[1] Small and medium enterprises in manufacturing are generally defined as those with fewer than 500 employees.

The Full Evaluation

This paper summarizes the results of our evaluation of CATD. Three reports (Volumes I, II, and III) together comprise the full evaluation.

Volume I is based primarily on a survey of industrial clients of CATD, supplemented by data supplied by CATD and by case studies of 19 companies with whom CATD has worked. The report focuses on mostly "evaluative" questions; it identifies, arrays, and analyzes the costs associated with CATD and the benefits that can be attributed to its activities to date.

Volume II focuses on what has been learned about the relationship between CATD activities and subsequent impacts on industry, the economy, and Iowa State University that can help CATD be more effective and efficient in fulfilling its mission. This report is based on 19 case studies of CATD client firms.

Volume III combines the results of Volume I with data from similar organizations and a major study of industry-federal lab cooperative research to "benchmark" CATD's achievements against others, thus placing the costs and benefits associated with CATD into comparative contexts.

Benefits and Costs Associated with CATD

This part of the evaluation focuses on three questions, each of which calls for different data to be brought to bear on them within different analytical frameworks.

What has been the economic impact of CATD during its seven years of existence?

Programs employ a range of inputs to engage in a variety of activities, which produce outputs or outcomes that in turn have impacts. Whatever impacts or consequences are measured, there must be some way of tracing them back through outputs and activities to initial resource inputs to the program or organization being evaluated. Thus the need to identify and measure each of these elements of CATD activity.

Figure 1 depicts these elements, the relationships among them, and the kinds of data used to measure different aspects of each. Note that we have identified three categories of impacts: those on ISU/CATD, those on CATD client firms, and those on Iowa and the U.S. In addition to arraying a full complement of benefits and costs associated with CATD, we also conducted a limited cost-benefit analysis of CATD to date and through 1998.

What is CATD's "additionality;" that is, what impacts and economic benefits can be attributed to CATD activities that would not have occurred if it did not exist?

To some extent this question is implied in the analysis required to address the first question. Only impacts attributable to CATD can legitimately be counted. Nonetheless, there are some additional data that can be brought to bear on this question.

In the survey of CATD companies, we asked about what companies would have done in the absence of CATD involvement, what savings and other benefits were directly attributable to CATD, and what the costs to the company would have been if they had obtained equivalent services and/or knowledge elsewhere. These data provide useful supplements and offer insights into the broader question of economic impact.

How effective has CATD been in bridging the gap between state and federal support of university research and commercialization of ideas generated from that research?

This question is partially addressed by the previous questions. However, it is useful to focus specifically on the particular mission of

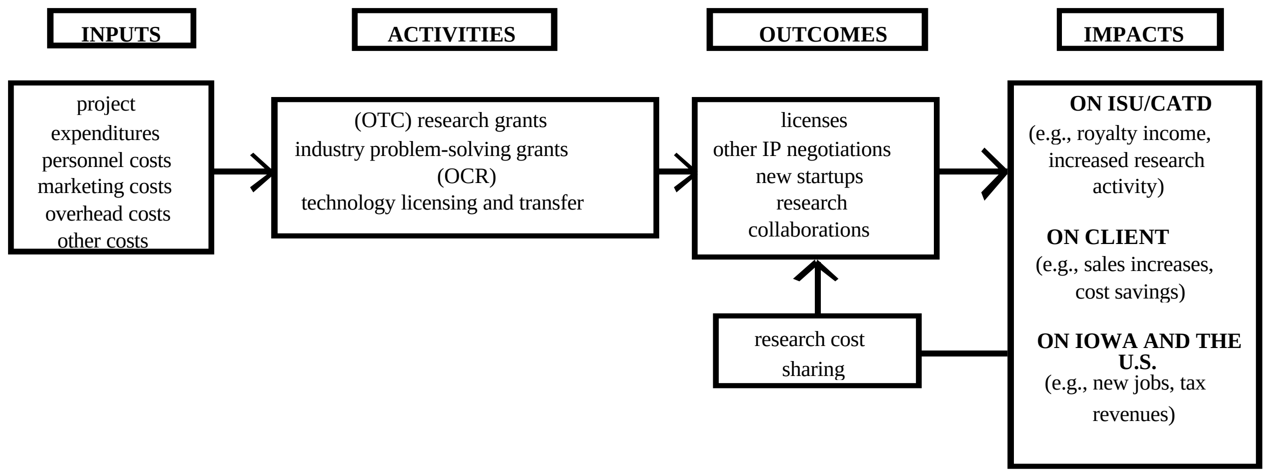

Figure 1. Schematic model of CATD operations

CATD: to span the "gap" (an assumed market failure) between university research and commercialization of the ideas resulting from that research. Both the survey data and case studies offer information about the existence of this gap as seen by industry, its severity, and the role of CATD in bridging it.

Inputs, Outcomes, and Impacts: A Summary

From CATD's creation in 1987 through 1995, the state of Iowa has spent $3.7 million, mostly for support of CATD's cooperative research and development projects with industry (Table 1).[2]

Over the same period, the U.S. Department of Commerce has spent $22.3 million on CATD, again primarily for research projects with commercialization of university technology or industry problem-solving as their objective. During this period CATD has supported approximately 100 research and development projects, identified more than 400 ISU technologies as suitable for licensing and made them available to industry, signed 60 licenses with companies, and spawned ten new Iowa startup companies.

CATD licenses have generated $533,000 in royalty payments (Table 2). Fourteen of the 56 firms responding to our survey have paid royalties to ISU. The average total payment over the period 1990-1995 for these 14 firms is just under $25,000, while the median is $500. CATD client companies have spent approximately $3.5 million on collaborative research with ISU ($3 million of this is from Iowa companies). This includes in-kind contributions. It is difficult to estimate what proportion of this investment was a direct contribution to ISU research. Eleven of the 56 firms responding to our survey of all CATD client companies reported hiring ISU faculty or students as consultants.

In deciding to become involved with CATD, most companies (more than three-quarters) are seeking to develop new products or processes or improve existing ones. Nearly all (88%) provided partial funding for ISU projects or invested money in cooperative research with ISU. Companies estimate that they spent $3.5 million (extrapolated from survey data) of their

[2] Benefits and costs attributable to CATD are separately arrayed in the Tables 1 through 4. Note that some of the benefits are not assigned a dollar value, that some are current and some are anticipated, and that the bulk of benefits will occur in the future. (All financial data are in current dollars.)

own resources, including labor and in-kind contributions, on CATD projects (Table 3). Three million dollars of this was spent by Iowa companies. The "typical" (median value of project investment) company spent $20,000 on its CATD project. Over the next three years, CATD client companies estimate that they will spend $11.7 million (extrapolated; not including one estimate of $130 million) to continue projects begun with CATD. For Iowa firms the figure is $11 million (the $130 million outlier is an Iowa company). The "typical" CATD client expects to spend an additional $15,000 over the next three years.

Twenty-four percent of CATD client companies would not have pursued the project they worked on with CATD at all, 18.5% would have delayed the project, and 20% would have pursued it in-house but at a reduced level of effort. Only 13% would have pursued the project as originally proposed. It is impossible to say what the consequences of these discontinued, delayed, or restricted projects would have been, but both our case studies and the literature on the management of innovation in industry point to the serious negative (sometimes fatal) consequences for the firm of delaying or terminating product development and improvement.

Table 1. CATD Public Investment Summary (1988-1995)

Iowa		**U.S.**	
State appropriations	$2.4 million	U.S. Department of Commerce	$21.9 million
Iowa Incentive Program	$0.9 million	U.S. Manufacturing Extension Partnership*	$0.5 million
Iowa Manufacturing Technology Center*	$0.5 million		
Iowa Total	$3.7 million	U.S. Total	$22.4 million

*Assumes MTC support for CATD is shared equally between Iowa and NIST.

Table 2. CATD Public Benefits Summary

CATD/ISU			**Iowa**	**U.S.**
Royalty payments	$0.5 million	Jobs created or retained, to date**	39	39
Industry support for cooperative research	a % of $3.5 million*	Jobs created or retained, future**	137	146
Faculty or graduate students hired	11 firms	New start-up firms	10	10

*An unknown proportion of this amount involves direct cash support of ISU research.
**Figures do not include the jobs created and expected to be created by one highly successful startup ISU spin-off: 90 full time and 55 part time jobs created, with an additional 50 expected to be hired in the next 2-3 years.

Table 3. CATD Private Investment Summary

	Iowa	U.S.
Expenditures for CATD projects	$3.0 million	$3.5 million
"Typical" firm's expenditure*	$20,000	
Anticipated follow-on expenditures**	$11.0 million	$11.7 million
Anticipated follow-on expenditures including outlier	$141.0 million	$141.7 million
"Typical" firm's anticipated follow-on expenditure	$15,000	

*Median value reported by firms surveyed.

**Over next three years.

Table 4. Company Benefits Summary

	Iowa	U.S.
New startups firms created	10	10
New or improved products or processes	68% of companies	
New or improved products or processes expected	84% of companies	
Sales increases*	$1.2 million	$1.2 million
Company estimates of total dollar benefits	$11.6 million	$14.0 million
"Typical" firm's estimate of total benefits	$40,000	
Avoiding project termination, delay, or restriction	Some firms attach dollar values to avoided delays in product development and introduction	

*63% of responding companies said "too soon to tell." Does not include approximately $5 million annual sales of highly successful startup not included in survey.

Ten new companies started up as a consequence of CATD. (Six of these responded to our survey.) Thirty-eight companies surveyed (68%) reported that they had introduced new products or processes, or improved existing products or processes, as a result of CATD. Forty-seven companies (84%) expect these kinds of results in the future as a consequence of their CATD involvement. CATD clients report that their sales increased by $1.2 million (extrapolated to all clients) and achieved other savings amounting to $205,000 (extrapolated). Most firms, however, (35 or 63%) said it was too soon to tell what the effect of their involvement with CATD would be on sales. CATD clients estimate that the total dollar benefits (not including costs) of their involvement with CATD was $14 million (extrapolated), with Iowa firms reporting $11.6 million worth of benefits (extrapolated). The "typical" CATD client estimated a gross benefit figure of $40,000. CATD clients surveyed reported that 39 new jobs (extrapolated) were created or retained as a result of CATD. All of these jobs were created or retained in Iowa. Iowa companies anticipated that 137 additional jobs would be created or retained in the future; all client companies estimated that 146 jobs would be created or retained (both figures extrapolated). The average number of jobs created or saved per Iowa company was 0.67, and the average number of jobs expected to be created or saved per Iowa company was 2.3. Equivalent figures for all companies were just slightly lower. CATD records show ten new startups resulted from their projects. Only Iowa firms reported sales increases resulting from their involvement with CATD; these were estimated to be $1.2 million (extrapolated). Adding data from the case study of the successful startup company increases these figures substantially.

Analysis of Benefits and Costs[3]

The benefit and cost data described above enabled us to conduct a limited benefit-cost analysis for CATD. The analytical categories and data elements used for the analysis are summarized in Table 5. The results of the benefit cost analysis are summarized in Table 6.

For the period 1988 to 1995, the analysis identifies program costs of $29.1 million and firm costs of about $6.0 million, for a total costs of $35.2 million (all in 1995$). The benefits identified by the firms amounted to $15.9 million (1995$), or a little less than one-half of the public and private costs. It should be remembered that our definition of benefits is specific and limited to those reported by firms and does not account for other public, quasi-public, and private spillover effects. In addition, many of the longer-run projects sponsored by CATD during this period had not come to fruition, thereby imposing costs without yet realizing benefits.[5]

For the period 1996-1998, anticipated further firm costs are estimated at $17.7 million, ongoing benefits to firms at $6.0 million, and imputed sales effects at $54.0 million (discounted present values).

Overall, considering the complete period, 1988-1998, the analysis estimates program and firm costs at $52.9 million and total benefits at $75.9 million, for a net benefit of $23 million. The overall benefit cost-ratio is estimated at about 1.4.

In looking at the flow of costs and benefits during the follow-on period, it is apparent that net benefits increase over time, as would be expected as successful projects begin to recoup and then more than recoup their initial and earlier development costs.

Benefits and Costs: Conclusions

The full benefits of public investment in "upstream" activities such as research and knowledge transfer will not be realized for years. Intermediate outcomes such as technology licenses are a positive indicator of the effectiveness of past investments and procedures, but the payoffs from licenses (for both the licensee and for the public) will not be realized in the short term. If 1994 represents the "steady state" of CATD technology licensing, then the stream of public benefits from that key indicator of CATD activities will not be fully realized until after the turn of the century.

One problem with estimating the impact of any research-based economic development program that affects individual firms is that the distribution of impacts on firms is almost always

[3] The benefit and cost figures used in this analysis do not match those reported in the previous sections for the following regions: program costs were converted into 1995 dollars using the U.S. GDP deflator; total private costs were estimated by taking the mean value of project costs reported by survey respondents, scaling up to all companies involved with CATD between 1988-1995 (n=112), and converting to 1995 dollars; total private benefits were estimated in a similar manner using survey data, using a different scale-up factor correcting for the fact that some firms terminated projects without deriving any benefits (83 firms did not terminate projects and are still in business); future benefit estimates were based on survey results regarding expected future employment effects of the CATD project. Expected job impact data were converted to associated sales effects at the employee/sales ratio reported by survey respondents in 1995, adjusted for future productivity growth and with a ramp-up to full-sales impact by 1998.

[5] It is also to be noted that the survey data excludes one apparently very successful business case associated with CATD sponsorship which, if it were to be included, would have a significantly positive impact on the identified benefits.

highly skewed: a small number of firms realize very large impacts, while the impact on most client firms is modest. (An appropriate analog is the distribution of payoffs from a venture capitalist's portfolio.) From an economic development point of view, the spillover benefits from the small number of highly successful clients dwarf those from the remaining firms.

Table 5. Benefit-Cost Analysis: Summary of Analytical Categories and Data Elements

Analytical Category	**Data Elements**
Investments made through 1995	CATD program costs, 1988-1995 Private company costs associated with CATD projects, 1988-1995
Benefits through to 1995	Private company benefits associated with CATD projects, 1988-1995
Costs anticipated, 1996-1988	Addition private investments projected, 1996-1998
Benefits anticipated, 1996-1988	Sales and other savings apparent in 1995 and expected to continue 1996-1998 Imputed new sales, 1996-1998

Table 6. Summary of CATD Benefit-Cost Analysis

	1988-1995 identified 1995$ millions	**1996-1998** predicted PV* 1995$ millions	**1988-1998** estimated total 1995$ millions
Costs			
Program costs	29.1		29.1
Firm costs	6.0	17.7	23.7
Total costs	35.2	17.7	52.9
Benefits			
Benefits to firms, realized	15.9	-	15.9
Sales, other savings, expected to continue	-	6.0	6.0
New sales, imputed from projected employment effects	-	54.0	54.0
Total Benefits	15.9	60.0	75.9
Net benefits	(19.3)	42.3	23.0
Ratio of benefits to costs	0.45	3.38	1.43

*PV = present value

Program evaluation data presented in summary form can mask this. For example, one survey respondent, an Iowa company, expects (with a high degree of confidence) to invest more than $100 million during the next three years. Should this occur, the spillover benefits would easily balance the state's investment in all other projects, even if only a minor portion of those benefits is attributed to CATD. Similarly, one highly successful ISU spin-off, whose product development was stimulated by a series of CATD research awards, has already generated 117 new jobs, and an additional 50 jobs are expected in the next 2-3 years.

A benefit-cost analysis based on total national investments and benefits through 1995 and on anticipated costs and benefits for the period 1996-1998 shows an increasing benefit-cost ratio each year from 1995 to 1998. In keeping with the long-term nature of payoffs from investment in research, the estimated benefit-cost ratio exceeds one first in 1996 (following an 8-year history of R&D investment) and increases each year thereafter. The assumptions underlying the analysis are conservative; if secondary and spillover effects were incorporated in the analysis, the ratios would almost certainly be larger.

The evidence indicates that CATD is on a path to stimulating positive regional economic benefits for Iowa and for the nation, a significant proportion of which would not have occurred in its absence. Client firms for the most part praise CATD's role. The distribution of client impacts shows that most clients experience modest benefits, a mix of direct economic and longer term, qualitative benefits, that together enhance the companies' competitiveness and thus contribute to regional development. At the same time, a handful of clients—mostly spin-offs in whole or part from CATD projects—are extremely successful. Their success disproportionately benefits the university, the region, and the state. This pattern is symptomatic of the risk inherent in research investments. Assuming that the distribution of CATD's future impacts will resemble the past, and that the magnitude of their public benefits will increase. The benefit-cost analysis reinforces this conclusion.

Case Study Results

During the summer and fall of 1995 we visited a total of 19 CATD client firms and conducted interviews with the project directors. The interviews were carried out with a structured questionnaire and lasted about two hours each.

The purposes of this part of the evaluation are three-fold. First, we detail how CATD has facilitated and managed ISU-industry research collaboration. The details help us peer into what is generally considered in the literature as the "black box" of the innovation process. Second, we document how CATD client firms assess the effectiveness of their interaction with CATD and attribute their technological innovation to CATD's goals and strategies. Third, we rank the cases according to several measures of "success," and search for patterns of interaction and procedures that appear to be associated with more successful cases. Overall, our intent is to provide CATD with detailed information about how its strategies and procedures affect client firms, so that CATD can be more effective and efficient in fulfilling its mission. To this end we focus on the following five issues:

1. The management of industry inquiries
2. The organization of university-industry collaborative research teams
3. The leveraging of public funds
4. Intellectual property management
5. The centrality of CATD's role in ISU-industry collaboration.

Using these issues as a structure to read across the cases, three basic types of university-firm interaction were apparent. In one type, a company identifies a problem or need and decides to seek a solution from an external source. Iowa State University is identified as the location of a possible solution to the problem, and an initial contact is made, usually with a professor at the university. The professor then contacts CATD, which works out a form of collaboration between the university and the company, typically involving a new research project with support from both parties. Patent or other intellectual property agreements are negotiated as necessary. We labeled this type of interaction as "**problem-solving**."

Another type of interaction begins in the same way as the first: a company identifies a problem or need and contacts Iowa State University looking for a solution. In this model, however, the company usually is aware that a potential solution already exists in the form of an available technology at ISU. Usually the technology has already been patented by ISU and considered by CATD as "available for licensing and commercialization." The research underlying the technology has been supported, at least in part, by CATD. The ISU contact in turn gets in touch with CATD, which negotiates a license or other intellectual property agreement between ISU and the company. We labeled this type of interaction "**off-the-shelf**."

In the third type of interaction, CATD decides to make an investment in a specific technology that appears to be ripe for commercialization. The researchers involved, often professors at ISU, form a new company to develop the technology. The technology usually is patented by ISU and licensed to the new company. We labeled this type of interaction "**startup**."

Assigning labels to the nineteen cases was not difficult; each one, with minor deviations, could be associated unambiguously with one of the three models. Nine of the cases (47%) were "problem-solving," four (21%) were "off-the-shelf," and the remaining six (32%) were "startups."

A scoring system was devised so that the cases could be ranked on six measures of outcome, as follows:

- Jobs created to date
- Capital expenditures to date
- Savings or sales increases to date
- Jobs expected to be created (over next three years)
- Capital expenditures expected (over next three years)
- Savings or sales increases expected (over next three years).

Cases were scored on each outcome measure on a scale of 0 - 3, with 0 signifying no evidence of impact and 3 signifying maximum relative impact among the nineteen cases. Scores were then averaged to achieve a mean rating for each case on *realized* and *expected* impacts. Table 7 displays the cases, ranked by realized impacts, showing the company code, type of model, impact ratings, and other selected variables.

For *realized* impacts, it is significant that three of the top-ranked four cases are startups, with mean realized scores of 1.67 or higher, substantially above the mean scores of the other 15 cases. Moreover, if the cases are split into upper and lower halves, 5 of the 6 startups are in the upper half. There is no obvious pattern of factors contributing to the scores of the top-ranked cases—the top four cases show sizable contributions from each of the three components of the realized score: jobs, capital expenditures, and savings or sales increases. For *expected* impacts (data not shown), the break point between significantly higher and lower scores is 1.83. Among the seven cases scoring 1.83 or higher, four are startups. Neither problem-solving nor off-the-shelf cases appear to be strongly associated with realized or expected impact scores, nor does whether OTC or OCR strategies governed the interaction.

Table 7. Mean Realized Scores of Case Study Firms

Company	CATD program	Model of Interac-tion	Jobs to date	Capital expenditures to date	Savings or sales increases to date	Mean realized score
			Score			
EAI	OTC	Startup	3.00	2.50	2.50	**2.67**
APA	OTC	Problem solving	0.50	3.00	2.00	**1.83**
FLM	OCR	Startup	1.50	2.00	2.00	**1.83**
CMP	OTC	Startup	2.50	2.50	0.00	**1.67**
AND	OTC	Problem solving	1.00	0.50	1.50	**1.00**
PFR	OTC	Startup	1.50	0.00	1.50	**1.00**
FWK	OTR	Problem solving	2.00	0.00	0.50	**0.83**
BMI	OTC	Problem solving	0.00	0.50	1.50	**0.67**
BFC	OTC	Startup	0.00	0.50	1.50	**0.67**
RUM	OTC	Startup	0.00	0.00	1.50	**0.50**
JMC	OTC	Off the shelf	0.00	1.00	0.50	**0.50**
MTL	OTR	Problem solving	0.00	0.00	1.50	**0.50**
PHC	OTR	Problem solving	0.00	0.00	1.50	**0.50**
VLP	OTR	Problem solving	1.00	0.00	0.50	**0.50**
ODR	OTR	Problem solving	0.00	0.50	0.50	**0.33**
SDL	OTC	Problem solving	0.00	0.00	1.00	**0.33**
ETC	OTC	Off the shelf	0.00	0.00	0.50	**0.17**
FSC	OTC	Off the shelf	0.00	0.00	0.50	**0.17**
DER	OTR	Problem solving	0.00	0.00	0.00	**0.00**

For the five startups that appear in the upper half of top-scoring cases,, significant amounts of targeted development support from CATD's Department of Commerce funding figure prominently. Here, substantial public investment yielded large payoffs both for the firm and for Iowa in the form of realized and expected economic development. Equally interesting, though, are the two cases in which small amounts of well-timed support yielded substantial benefits. A balance of longer-term, substantial investments in promising areas of technology and much smaller but carefully timed, short-term support help launch startups whose payoffs, both public and private, tended to be larger than those from other types of investments.

Placed within the larger context of CATD's portfolio of projects, the highly successful cases illustrate the skewed distribution of payoffs from investments in risky endeavors like research. There is apparently no predictable set of characteristics or procedures that, if followed in a particular case, would increase the likelihood of payoff. On the other hand, if benefits taking the form of jobs, capital investments, and cost savings or sales increases are desired, the case study analysis suggests that CATD's portfolio should contain a substantial number of potential startups.

Conclusions from the Case Studies

Aside from a few instances in which the problems are beyond CATD's responsibility, CATD client firms express a high degree of satisfaction with CATD's personnel. They report that CATD personnel are helpful, professional, and trustworthy. Some noted that CATD personnel went an extra mile to help them on several occasions. Our interviews led us conclude that, with a few exceptions, there is generally a strong sense of trust that prevails between CATD and its client firms.

More importantly, client firms see CATD as a significant influence on intra-firm technology commercialization and problem solving. Most firms attribute substantial amounts of their technological advancement or business expansion to CATD's efforts. The prevailing commentary is, "In the absence of CATD, [ISU-industry] collaboration would not have taken place."

In spite of the generally favorable climate portrayed above, CATD-industry relationships are not without strain. The strain originates from the larger university system of which CATD is a part. To many industrial firms, especially established ones, negotiations over intellectual property rights become a source of tension and irritation. A careful reassessment of ISU's intellectual property management policies appears to be in order. Another problem relates to the cultural difference between the university and industry. The dilemma is a classic one: "Why can't academics think like a business." To this the academics respond: "Why can't industry understand that the university has other important missions—teaching and research?" One role of CATD and its personnel is to bridge the two cultures, and in this CATD has established a strong foundation and a positive reputation.

The most common pattern of interaction we observed among the 19 cases begins when a firm contacts an ISU researcher for assistance or collaborative research. The scientist or engineer then refers the request to CATD. CATD then negotiates with the inquiring firm and develops a plan for ISU-industry research collaboration and technology transfer, including intellectual property provisions. It is significant that this was the pattern in only two of the six startups; the majority of startups resulted either from relatively early, large-scale investments CATD had made using Commerce Department funds or from smaller, more recent support intended to facilitate the startup process itself.

In terms of realized payoffs from investments in collaboration, it is clear that startups contribute disproportionately to the overall public and private benefits, as measured by company estimates of jobs, capital expenditures, and savings or sales increases. In keeping with the uncertainty and risk inherent in the research and development process, no clearly identifiable *a priori* characteristics, investment strategies, or administrative procedures manifested themselves that would enable CATD to predict project outcomes more accurately. On the other hand, the case study analysis suggests that CATD should attempt to identify promising startup opportunities. If chosen carefully, these investments yield proportionally larger benefits for the firm, for Iowa, and for the larger economy.

Benchmarking Analysis

Background

Benchmarking programs such as CATD presents formidable challenges to analysts and evaluators. Nearly all state cooperative technology programs combine several types of cooperative activities, and the relative emphasis on each of them varies widely even among programs that employ similar strategies. One implication of this situation is that it is extremely difficult to identify fully comparable programs; intimate knowledge of potential comparables is highly desirable to avoid invalid comparisons. A second complicating factor is that data on program outputs and impacts, the categories of interest for most benchmarking efforts, are difficult to obtain and, when they exist, frequently do not employ identical measures. Independent evaluations of these programs, which might provide some comparable output and impact data, are exceedingly rare. For these reasons, we used three different approaches to benchmarking CATD outputs and impacts:

1. Data from the FY 1993 survey of members of the Association of University Technology Managers;
2. Four selected state cooperative technology programs;
3. Bozeman, Papadakis, and Coker survey of companies conducting cooperative research with federal laboratories (the “Fedlab” study).

First, surveys of member universities by the Association of University Technology Managers provide a broad context within which CATD’s licensing and cooperative research activities can be placed. Although focused at the university rather than technology licensing or transfer organization level, FY 1993 AUTM data on research expenditures, licensing revenues, and patents for the top fifteen universities in the U.S. (of which Iowa State is one) provide some indication of the relative size of the pool of research results from which CATD can draw and of Iowa State’s relative success in transferring technology to private industry for commercial purposes.

Second, evaluations of a few state cooperative technology programs that provide output and impact data are readily available. With appropriate and extensive caveats, we compare data from recent evaluations of New York’s Centers for Advanced Technology, Alaska’s Science and Technology Foundation, Virginia’s Center for Innovative Technology, and Pennsylvania’s Ben Franklin Partnership.

Finally, in accord with the evaluation design, we compare selected results of the survey of CATD clients with data from a study of cooperative research relationships between federal laboratories and private companies. This comparison constitutes the bulk of our benchmarking analysis. At first glance this might seem less appropriate than comparisons with university-industry cooperative research, but the benefits of doing so outweigh the shortcomings. As noted above, there are very few independent evaluations of state industry-university cooperative research programs that collected detailed project cost and benefit data even remotely comparable to that collected in the

CATD study. The CATD evaluation was designed to take advantage of the unique data base developed from a survey of companies that engaged in cooperative research with federal labs, similar to the arrangements between CATD and its clients. Thus, selected items in the CATD survey were identical to those used in the Bozeman, et al., study, permitting direct comparison of data for those items. Also, in many respects the relatively narrow objectives of CATD projects make them, in aggregate, more comparable to an aggregate of federal laboratory-industry cooperative research projects than to most of the much more diverse state cooperative technology programs which, unlike CATD, typically include activities such as incubator support, technical assistance, and direct financial support to firms.

Iowa, Iowa State University, and CATD in Comparative Context

Iowa ranks 29th in state spending on cooperative technology programs and 27th in spending per capita on such programs. On most measures of university R&D spending and of the extent to which universities capture economic value from their research, Iowa State University ranks among the top 15 universities in the country. According to 1993 data, ISU is among the top five universities on several key measures of the effectiveness with which universities foster a climate conducive to identifying potentially commercializable technology, transfer it to private industry, and realize economic value from it.

Compared with four state technology-based economic development programs, CATD is narrowly focused, emphasizing university-based cooperative research with industry to promote technology development and commercialization. Its record of licenses signed during its seven-year history appears to be strong compared with the other four programs. Other programs report much higher rates of job creation than CATD, but direct job creation is not necessarily a valid measure of effective technology transfer, increased firm competitiveness, or even regional economic development. Moreover, job creation data at the state level are notoriously subject to upward bias.

Benchmarking CATD against Federal Lab-Industry Cooperative Research Projects

A study of 229 cooperative research projects between federal laboratories and companies afforded a better basis for benchmarking CATD's results. Indeed, our survey instrument was designed to generate data that could be compared directly to the Fedlab study. Federal lab-industry projects were substantially larger than CATD projects, and Fedlab projects were more widely varied in size and cost than CATD projects. In addition, the Fedlab results were skewed by a few very large projects. The "typical" (median) Fedlab project's benefits equaled its cost, whereas the benefits of the typical CATD project were twice its cost.

The more highly skewed distribution of Fedlab projects showed up in several different ways of comparing project benefits and costs. The mean marginal benefit of the larger Fedlab projects was nearly five times that of CATD. The median marginal benefit for lab projects, however, was zero, while the median marginal benefit for CATD projects was small but significant (see Table 8). A comparison of both the mean and median ratios of "market value" (company estimates of the cost of CATD services and benefits if purchased elsewhere) to project costs showed that the CATD projects were a somewhat better "investment" (Table 9).

Table 8 Comparison of Mean and Median Marginal Benefits

	CATD Study			Federal Laboratory Study		
	Project benefit	Project cost	Marginal benefit	Project benefit	Project cost	Marginal benefit
	$ thousands			$ thousands		
Mean	301.0	42.2	264.9	1,548.1	448.8	1,087.6
Median	40.0	19.0	14.0	100.0	100.0	0.0

Table 9 Comparison of Market Value of Projects

	CATD Study		Federal Laboratory Study	
	Market value	Market value ÷ Project cost	Market value	Market value ÷ Project cost
	$ thousands	ratio	$ thousands	ratio
Mean	65.1	3.34	490.7	2.69
Median	45.0	2.50	100.0	1.00
Maximum	300.0	33.33	10,000.0	40.00

CATD projects were no more successful in direct job creation than the federal laboratory projects. Neither the CATD projects nor the federal laboratory projects were major producers of jobs. This is not surprising, given that companies do not seek collaborations with federal laboratories or universities to create jobs. More likely, such collaborations lead to cost savings and product improvements that enhance competitiveness but have no effect whatever on overall employment, at least in the short run.

One conclusion seems clear in comparing the costs and benefits of the CATD projects and the federal laboratory projects. The federal laboratory projects succeed in the sense that the aggregate value they provide is quite substantial, despite the fact that the "typical" project has relatively little impact (at least in the sense of marginal benefit). By contrast, the CATD projects have a higher and more stable success rate, but these smaller scale projects have less potential to produce the multi-million dollar winners that redeem the entire "investment portfolio." Relative to the Fedlab projects, CATD projects can be characterized as "safe bets, yielding a good return." Note, however, that if the one CATD project, an outlier from a job-creation point of view, that was not included in the survey data were to be added to the portfolio, CATD's distribution of project benefits would more closely approximate that of the Fedlab set.

Implications for Public Policy and Management of University-Industry Cooperative Research

CATD employs an unusual blend of strategies to bridge the gap between university research and industrial application. As a source of support for university researchers whose ideas may have commercial value, CATD resembles a venture capital firm with a willingness to invest in projects that are too risky and/or long-term to attract private investors. As an organization seeking to license university technology, CATD resembles the university technology licensing offices found on the campuses of nearly every research university in the U.S. CATD's portfolio of investment in research projects has varied significantly over time, shifting from relatively large ($100K +) projects with multi-year time horizons and relatively broad objectives to smaller projects ($10K-50K) with narrow objectives, greater industry involvement, and expectations of payoff in a year or less. This has not necessarily been the result of strategic planning, but largely a response to shifts in the sources of financial support for CATD. These variations offer an opportunity to assess the value of various strategies for commercializing university research. Identifying the strengths and weaknesses of different commercialization strategies should enable CATD to respond proactively to shifts in its support.

From a public benefits perspective, CATD's blend of a source of research support and locus for technology licensing appears to have generated greater value that would be expected from either activity alone. CATD's ability to invest in risky, long-term, broad areas of research of potential interest to industry generates a pool of knowledge that, seven to ten years hence, generates patentable technologies. Arguably, because of CATD's other mission—to license existing university technology—these investments are more likely to yield patentable technologies than "typical" university research. Moreover, the short-term, "problem-solving" research projects keep CATD staff continually tuned to industry interests. Thus, there appears to be synergy between the research support and technology licensing modes of CATD operations. It is not clear how much of this mutual learning takes place as a result of explicit planning and feedback or simply occurs informally, but it is likely that both CATD and other, similar organizations would benefit from a more detailed examination of the interplay of these strategies than we were able to accomplish. In the short term, for CATD the issue is moot because of the disappearance of what amounted to institutional support from the U.S. Commerce Department.

Universities seeking to maximize royalty income from their research can alienate the industry "customers" they wish to serve. The case studies showed that small firms can have difficulty obtaining bank financing or venture capital if the intellectual property to their proposed product is retained and exploited by a university. Furthermore, insistence on squeezing maximum dollars from each university patent can impair university-industry relations. In one case, ISU was willing to release intellectual property to a local small business, but only for higher royalties. The CEO said, "It is a shame we cannot work with our own state university because of the intellectual-property problem." In CATD's case, this problem appears to be a matter of university policy. Given the increasing pressure nationwide from state Boards of Regents and legislators to augment university income with royalties from university patents, we are concerned that the primary value of university research and researchers to industry—access to students, state-of-the-art knowledge, and unique facilities—may become victim to immediate, but misguided, fiscal demands. Moreover, emphasis on direct benefits such as royalty payments can redirect attention away from the much larger value that these indirect kinds of benefits yield in the form of public goods and externalities.

The CATD evaluation illustrates nicely that payoffs, both public and private, from university-industry cooperative research is long-term and not appropriately measured primarily in jobs created or retained. Most of CATD's client firms said it was too soon to tell what effect their CATD project would have on company sales (and this after seven years of CATD's existence); significant licensing activity from CATD-sponsored research did not emerge until 1994, six years after CATD began operations; the benefit-cost analysis showed steadily increasing benefit-cost ratios, but ratios that exceed one only after 1995. Most CATD client companies sought new or improved products and processes as their primary reason for working with CATD. While new jobs might result from achieving some of these goals, process improvement may actually reduce employment in the short term as production efficiency increases.

According to our case study analysis, the greatest public and private benefits from CATD projects were associated with startup companies whose beginnings could be attributed in part or whole to CATD support. In all likelihood, the survey data would have supported this result if one outlier startup, the subject of a case study, had also responded to the survey. The Fedlab study, as well as many other studies and evaluations of investment in research, show that (at least in "successful" programs) a handful of projects yield the vast majority of payback, easily swamping the modest payoffs and losses from the bulk of projects. The fact that public and private benefits from investment in university-industry cooperative research are distributed across projects in a highly skewed manner presents substantial problems in strategic management. Our classification of CATD cases into three categories and crude ranking system provided limited but promising insights. Some of the big "winners" were startups assisted by substantial, long-term funding, while others were firms whose startup was facilitated by small but targeted and timely support from CATD. We think that a more detailed examination of CATD's portfolio and the (perhaps implicit) strategies that underlie each project would be of significant managerial value. The inability to predict with certainty which projects will pay off means that CATD, and other university-based organizations that combine research project support with technology commercialization missions, should maintain a “balanced” portfolio of long- and short-term projects (the latter to ensure strong ties to industry and a stream of short-term but visible benefits), and continually seek to identify opportunities to assist startup companies.