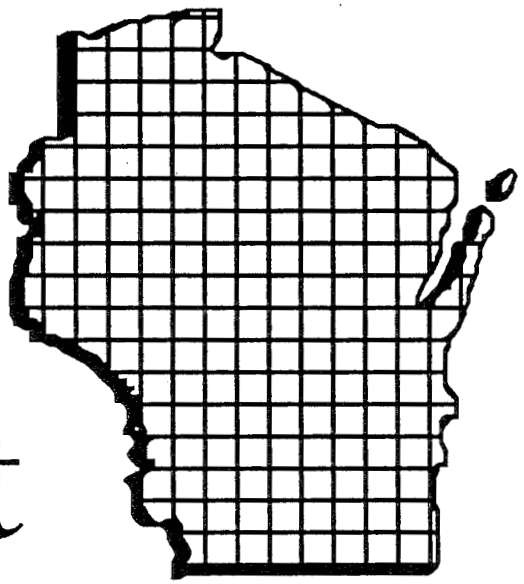
Wisconsin

Policy Research Institute Report



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KNOWLEDGE AND TECHNOLOGY TRANSFER IN WISCONSIN

Linkages Between Universities and Industry

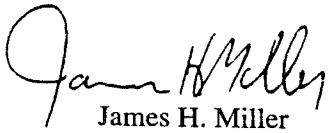
Report from the Executive Director:

For the last decade, most states have entered into a field called technology transfer. The purpose of this was to develop high-tech industries and jobs by linking universities and industries. To see how Wisconsin compared to the rest of the country we hired two researchers from Penn State with national reputations in this field. They developed questionnaires and interviewed key people from Wisconsin's academia, industry and government. Their report indicates that Wisconsin is doing much better than the general public perception in knowledge and technology transfer. The researchers believe that few states are doing all that well to start and many of the existing state policies involving research parks and incubators have not been very successful.

The strength in Wisconsin appears to be at UW-Madison and the Milwaukee School of Engineering. What is interesting and to a certain degree unusual is that the authors find transfer programs being faculty-driven rather than institutional-driven. At MSOE, 95% of its research money came from private industry and not from the government. Professors there were expected to teach and develop industrial linkages.

As we enter into the 21st Century there is no question that knowledge and technology transfer will become more important as Wisconsin's business competition becomes global. There is definitely room for state funding in this area. This report points out a peculiar Wisconsin bias that has tended to discourage faculty and industry relationships rather than encourage them by requiring faculty to report all income over $5,000 which tends to intimidate and stifle faculty participation in these projects. One of the authors' ideas is to set up a matching-grant program for Wisconsin faculty who cooperate with industry. This type of program would have minimal administrative costs and would encourage Wisconsin business to use the faculties at Wisconsin universities. From an academic perspective, this would encourage professors to apply their research for industry benefits rather than for the Federal government.

This type of cooperation could be extremely useful for Wisconsin in developing new high-tech businesses and jobs for the 21st Century.



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Knowledge and Technology Transfer in Wisconsin

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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

BACKGROUND

State programs in science and technology in the late seventies and eighties were largely responses by governors to the steady downturn in the manufacturing sector of the economy, which in the northeast had become a serious problem. They were also responding to international competition and the perception that the employment base needed to be channelled into new directions. One element in the responses of states was to try to promote new business and industry, and one element of that response was to attempt to stimulate the transfer of outcomes of academic research into the market. There are many steps in the commercialization of academic research, and most of those steps are in the control of industry and business. However, it was thought that more university-industry coupling would help the economy. In addition, university administrators perceived that new linkages with industry could be both good public relations (especially useful when state university presidents go to legislatures for funding) and shore up flagging university funding with additional outside resources. Both federal and state governments designed programs in an attempt to create a more diverse, innovative economy through partnerships between university research and industry. The buzzwords "high-tech," "chip technology," "biotechnology," and "computer software" were repeated somewhat like a religious incantation with no analysis of how knowledge is transformed into products. By the mid-eighties a variety of initiatives were underway in most states.

This study focuses on Wisconsin university models for assisting state industry. The sample includes the Dairy Center at Madison as well as four of the five engineering schools of the state: UW-Madison, UW-Milwaukee, Milwaukee School of Engineering, and Marquette University. In addition, the study includes five organizations set up to facilitate linkages between business/industry/faculty or to aid in some aspect of technology transfer. They are: University-Industry Research Program, Madison; Wisconsin Alumni Research Foundation, Madison; Research Park, Madison; the Office of Industrial Research and Technology Transfer, Milwaukee; and the Medical College of Wisconsin Research Foundation.

In discussing and evaluating the attributes of these arrangements to promote university-industry linkages, we include comparative data from other states and from federal programs, where relevant. Research parks and incubators are also discussed in comparative perspective.

Finally, the study addresses several questions that are troublesome whenever the subject of "university-industry" relations is examined and gives some of the major conclusions from the literature, as well as our own, on those questions.

FINDINGS

1. The University of Wisconsin-Madison and the Milwaukee School of Engineering (MSOE) score high on their working alliances with industry. Most outstanding is the long-term cooperation of MSOE with industry. Less than 5 percent of MSOE research funding comes from government sources; the bulk is from industry. MSOE outreach to Wisconsin business and industry is impressive in both State and national perspective. They have successfully encouraged faculty to do applied research and have acknowledged such research/consulting as legitimate faculty-development activity and thus integrated it into the culture of academia. In addition, MSOE has integrated consulting and project experience into the education of engineers in a way that could be a model for the nation.

Because of the quantity of research work at UW-Madison, which prohibited looking at research links to industry in all fields, we focused upon the efforts of the College of Engineering and the Dairy Research Center. In addition to Madison's success in accomplishing world-class academic research, we found flourishing links with industry, although personnel is overextended for the resources available. (See conclusion 6.) A sample of 24 engineering consortia at Madison revealed that 44 percent of the businesses involved are Wisconsin businesses. About one-third of the consortia partners are small businesses, which is high participation for small business.

2. Links with industry at UW-Milwaukee are less-developed than at Madison. The Office of Research, Innovation and Technology Transfer, which is funded on a continuing basis by the legislature, is trying to stimulate faculty interest for linkages with industry and to identify industrial needs and interest. Their efforts are predominantly at this start-up level.

Engineering education at UW-Milwaukee would improve if more links could be forged with industry for the purpose of integrating knowledge of industrial needs into teaching, as MSOE has done.

3. The University-Industry Research Program, Madison, offers referral services, essentially spreading information about how to find information. Survey results show that businesses that use the Research Program for referral find the services helpful. Enhancements to funding for the Program may be appropriate, especially to enable them to keep statistics that will provide funders with data for evaluation. Although the Program has been in business for 25 years, it cannot provide data on crucial categories such as technical problems addressed, geographical distribution of users, dollar benefits estimated by users, users by size, and so forth.

University-Industry Research's services at Madison should not be duplicated by other state agencies, which would merely add to confusion among business about whom to call for access to resources of the university.

4. The Medical College of Wisconsin Research Foundation and Research and Resources, Inc., together provide a multifaceted and labor-intensive effort to identify intellectual property that may emerge from the research labs and then to transfer that technology into the economy. That is, the goal of the College is not just knowledge transfer but true technology transfer. The cost of such an operation in the U.S. requires around $100 million, while royalties on patents yield about $3,000 per million dollars of research, except for the big winners. Thus it is doubtful that the College's Research Foundation model is one that either private or state education institutions will be able to follow effectively.

5. The Wisconsin Alumni Research Foundation targets specific technological areas and, thus, cannot serve every research area of the university. It is viewed as of little help for patenting, and especially licensing, among the engineering researchers at Madison. Special patenting and licensing units could, of course, be set up to serve areas of research that the Foundation chooses not to handle. But, unlike the Research Foundation, most university patenting offices in U.S. education institutions are not realizing income above costs of their operation, and, thus, initiating such offices would likely be a poor investment. The Research Foundation, due to chance and good management, has demonstrated a uniquely successful model of patent management and their judgments on what they cannot do appear valid to us.

6. With a few exceptions, establishing research parks has not led either to interaction between industry and university faculty or provided endowments for research. The efforts in this regard of the Research Park at Madison are too new to be evaluated.

7. For the most part, the product of the university is knowledge, not technology. Inappropriate development policy may result from confusing the creation of commercializable products, that is transferring technology, with efforts to assist industry through research. That common error should be avoided in planning processes.

8. For reasons discussed in this report, encouraging universities to institutionalize interdisciplinary structures may be the State's most important policy input into university life in regard to strengthening links with industry.

9. The State has made positive efforts to link the knowledge developed in its universities to Wisconsin business and industry, especially under the Wisconsin Technology Development Fund. However, those efforts have been aimed primarily at initiating linkages. Another fundamental need--to financially support established university-industry relations--has been neglected by Wisconsin when compared to other states.

Existing university activity with industry has been building for some years and has been largely faculty-driven. Industry has backed its judgement of research with hard dollars contributed to consortia. In that sense, these alliances have been guided by market pull, which offers the best chance of success.

However, as a result, faculty who created and maintain the consortia and centers in our engineering and dairy sample are over-taxed with administrative duties that have little to do with teaching and research. Given the press from all sides to increase the outreach mission of the universities, this situation will persist and worsen, draining off faculty talent into administration. In addition, in the absence of additional funding, the instructional budget is in danger of being pirated to sustain such activity.

RECOMMENDATION

Establish a State grant program that would match at rates of "x" to 1 every research dollar (no in-kind or gifts) provided by industry for research at any of the Wisconsin education institutions. The matching ratios could be increased for Wisconsin-based companies. The money could supplement the corporate project effort in whole or in part, or it could be "seed money" for often high-risk research. The State would have the assurance that this work would be done by faculty that have a proven dedication to working with industry.

The advantages of this system are manifold:

- A review system that is the most pertinent and honest one available to innovation research since it is based on past performance and backed by industry's own dollar investment.
- Absolute minimum administrative cost.
- Conservation of valuable time of faculty and industry.
- A budget that is very easy for the State to fine-tune. For example, the ratio x:1 could be increased for Wisconsin companies; it could be increased or decreased for particular fields that the State wishes to emphasize or deemphasize; it could go up or down slightly with economic cycles.

II. SUMMARY OF FINDINGS

WISCONSIN'S UNIVERSITIES, COMPARED TO OTHER STATES, SCORE HIGH ON UNIVERSITY INITIATIVES FOR ALLIANCES WITH INDUSTRY

A sample of 24 of the engineering consortia/research centers at Madison indicate the following:

•Industry contributed nearly $4 million to research at Madison in 1989. Faculty perceive that, even during a long-term downturn in industrial investment in research, industry is willing to invest in consortia because:

(1) industry can use the links to recruit better personnel; this is the primary consideration from industry's side.
(2) state-of-the-art research is being done.
(3) research matches the sponsor's interests.
(4) of the possibility of patentable or commercializable products eventually resulting from knowledge transfer.
(5) new ideas for new, in-house research may emerge.

•44 percent of the businesses in the consortia are Wisconsin businesses. This is a good mix when compared to national averages. Bringing in out-of-state partners increases the benefits for Wisconsin partners in a consortium.

•One-third of the members of consortia have less than 500 employees and, thus, fall under the category of small business. Comparable national data indicate that this small business participation is relatively high in Wisconsin.

•Alliances are not merely producing a flow of information outward from the universities; industrial sponsors are actively engaged in a two-way flow of information; industrial personnel help present information at seminars, etc., lead joint educational programs, and, in general, participate in interchange. This two-way flow is crucial since faculty must have continuous information in regard to what is needed by the industry. The situation would be improved further by more faculty time on the "shop floor" of industry, which is very rare, and additional time spent by industrial personnel in university research labs.

•Consortia are the result of faculty initiative not necessarily a response to RFPs (requests for proposals) or other financial carrots.

•There is a "knock-on" effect of consortia; other businesses hear of what is being done and contact the researchers for feasibility studies and advice. Thus, the effects of consortia research spread beyond consortium members.

•Thus far, consortia activity has been faculty-driven, and, unless a modest amount of support personnel is added for university-industry alliances, teaching time and instructional budgets will necessarily be pirated.

DAIRY CENTER, MADISON

Knowledge transfer from dairy research is crucial to the economic development of the State. It is an excellent example of building on strength. A study of the Dairy Center indicates:

•Problem-focused research has meant large dollar savings to the industry.

•Research is closely linked with market needs.

•Knowledge-transfer structures work well.

•Researchers themselves develop the expertise to make the knowledge work in the industry. This is desirable, but rare, in university-industry linkages.

•However, research time of top-notch faculty is being siphoned off into administration; here too some modest administrative help should be provided.

•Money flows out of state for research that could be done in Wisconsin, given sufficient personnel.

UW-MILWAUKEE

UW-Milwaukee engineering faculty have comparatively few industrial alliances; those which exist center around half a dozen faculty. They work almost exclusively with large companies and get their major funding from federal government agencies. Getting large, multi-year grants is the most cost-effective way for them to support research. Getting research money from industries is very time-consuming and, furthermore, such funding is minor and usually short-term.

The value of the UW-Milwaukee to small companies will probably continue to remain that of providing well-educated engineering graduates. However, to that end, UW-Milwaukee could improve the links with industry for teaching purposes in some of the ways done by MSOE.

MILWAUKEE SCHOOL OF ENGINEERING

The history of MSOE in industry-university cooperation is a long and flourishing one.

•MSOE encourages faculty to do applied research consulting as part of faculty development. Ninety-eight percent of the private consulting is done on site in industry. This facilitates learning on the part of the company employees and also serves to familiarize faculty with what is happening in industry.

•Consulting experience then feeds into the classroom.

•40-60 projects are done each year for industry by students.

•In addition, each year over 100 industrially-sponsored, applied research projects are done in the Applied Technology Center by faculty and students; sponsorship for 1989-90 amounted to about $500,000.

Overall, MSOE has succeeded in integrating an education process with assistance to Wisconsin industry in a manner that could be a model for other urban engineering schools in the nation.

MARQUETTE UNIVERSITY

Traditionally a teaching institution, Marquette has, however, begun some initiatives for linkages with industry and is promoting a healthy variety of industrial contacts that use

Marquette research in agriculture, electronics, environment, fluid systems, manufacturing systems, and medical technology. They also do testing for industry, have a very vital program of continuing education serving the electrical power industry, and do some new product development with manufacturing firms, who fund the projects.

MILWAUKEE ENGINEERING CONSORTIUM (MEC)

The three Milwaukee engineering schools formed an engineering consortium in 1988 to increase and coordinate their contacts with industry. It is a noteworthy example of new regional coalitions of institutions that are necessary for the efficient use of resources of the colleges and universities in the U.S. that are not big name research institutions and not major federal grant recipients but have something to offer to industry. This could be a useful area for the State of Wisconsin to invest resources.

SPECIAL OFFICES FOR LINKING UNIVERSITY ENGINEERING RESEARCH AND INDUSTRY

UNIVERSITY-INDUSTRY RESEARCH PROGRAM, MADISON

•Information/referral/university public relations are the primary functions.

•From interviews with a sample of users, we found that those who have called the University-Industry Research Program report finding the services helpful. Most call more than once.

•The Program conducts approximately 15 company briefings per year. Their purpose is for future reference rather than any immediate technical knowledge transfer. The Program should do an evaluation to determine whether investing this considerable faculty time in public relations is the best use of resources.

•Cooperates with the Department of Development in grant review and helping Small Business Innovation Research clients, as well as helping those interested in other Department initiatives, to write proposals. As an arm of the Graduate School, this function of the Program seems out of place.

•It would be useful for the University-Industry Research Program to have the capacity to keep statistics on services, such as categories of technical problems addressed, geographical distribution of users, dollar benefits as reported by users, users by size of business, private/public, start-up/established firm, and so forth. Since this is a line item in the state budget, it would be valuable if the Program had the resources to collect such data, over the long-term, for presentation to the legislature.

INFORMATION SERVICES DIVISION--WENDT ENGINEERING LIBRARY

•The Information Services Division receives over 20,000 calls annually; it works in conjunction with the University-Industry Research Program, but, unlike the Program, is a self-supporting service. The Division provides users with information from 400 national data banks, from a complete collection of U.S. patents, and the holdings of the UW-Madison library system.

Together University-Industry Research and Information Services Division provide a complete referral/information system. Their services should not be duplicated. Alternative information/referral services will serve to confuse business in regard to the channels for

contacting the university. The exception might be an enhancement of the referral service of the Office of Research, Innovation, and Technology Transfer at UW-Milwaukee (see below).

WISCONSIN ALUMNI RESEARCH FOUNDATION

The Wisconsin Alumni Research Foundation provides successful patenting and licensing services. It is by far the most visible in the nation, and possibly misleads others in trying to copy it. We find that its secret is that it does not attempt to serve every research area of the university equally. It has targeted areas in the bio-health-consumer area, and has succeeded by concentrating its legal skills and the ability to police and defend its patents. The engineering faculty have found the Foundation of very limited use in patenting and licensing. Other patenting and licensing units might be set up, but, bearing in mind the financially-marginal nature of most university patent offices, to do so would likely be a poor investment in university resources. Alternate arrangements utilizing the patenting skills of potential industrial licensees of faculty inventions need to be explored. They involve no financial risk and may do better for a wide variety of areas.

OFFICE OF RESEARCH INNOVATION AND TECHNOLOGY TRANSFER, UW-MILWAUKEE

Unlike University-Industry Research, the Office of Research Innovation has been in existence for only a few years. The office works directly with faculty, stimulating their interest in linkages with industry, identifying problems of industry and, then, matching the two. They also follow up on nurturing those relationships.

Unlike the Alumni Foundation, which has more faculty interest in patenting than it can handle, the Office of Research Innovation promotes patenting, since there is little activity in this regard at UW-Milwaukee.

MEDICAL COLLEGE OF WISCONSIN RESEARCH FOUNDATION

This unit, working in tandem with the for-profit subsidiary, Research and Resources, Inc., facilitates the entire process of knowledge and technology transfer from research to product, that is, it functions from the early point of identifying intellectual property for transfer to finding a match with the right entrepreneur. Part of its success stems from the fact that it recognizes that transfer is best accomplished with constant dialogue between researchers and business.

This model of technology transfer is very labor intensive and expensive. Thus, the cost of creating several of these units would be prohibitively expensive. Further, due to some of the specifics of the Medical College's research, it is doubtful that the model could be successfully transferred to other research institutions.

STATE PROGRAMS IN SCIENCE AND TECHNOLOGY

The faculty of the Wisconsin education institutions studied for this report have initiated a variety of arrangements to work with industry for knowledge generation and transfer and, in comparison to other higher state education systems, this part of the Wisconsin configuration of university-industry cooperation would rate an A grade.

Since the faculty-driven activity with industry has been successful, rather than copy other states' unevaluated economic development initiatives, it might be best for the State

government to build on that foundation. Using state funds for initiatives by faculty that build on the already substantial experience with industry and willingness for inter-institutional cooperation would no doubt be the most likely to succeed. There is a danger that State funding targeting inexperienced groups who have not shown either inclination or competence in working with industry will mean re-inventing the wheel. Care should be taken that any new Department of Development programs are not redundant (for example, information/referral services) and are made available to those with track records. Recent research shows that track records and not proposals are the best predictor of success.

Among the initiatives taken by states to support knowledge transfer from their universities to industry, competitive research grants, based on a substantial proposal writing and review process, are prominent. Grants comprise approximately 25 percent of all state funding for science and technology development programs, and most require matching funds from industry. In terms of state dollar commitments, grant programs are second only to centers of excellence. However, there is very little evidence that the state-level bureaucracies established to review proposals achieve anything useful if real industrial matching funds are involved. We believe that it is self-evident that an industry which is investing tens of thousands of dollars per year in a university project does by far the most thorough peer review. Hence we believe that a simple matching grant program, could be used for providing state incentives for encouraging university research in the general area of technical interest represented by the industrially-funded project. The formula match is by far the most flexible policy instrument available to a legislature. The ratio can be adjusted for budget realities, or to emphasize any technical areas, or to favor state business, etc. This matching program could also favor the possibility of inter- and intra-institutional cooperation, which could bring in new faculty who have an interest in working with industry but have not done so earlier.

RESEARCH PARKS

There is little evidence for the success of research parks, based particularly on local university expertise, as instruments of technology development (as distinct from land development.) In general, research parks have a high rate of failure. The success of Boston's Route 128 and Silicon Valley had nothing to do with university initiatives. The truth is that no one yet knows what elements are necessary to insure knowledge transfer from university to business to commercializable product; most of the lists of what will make research parks work are merely compilations of everything that has been tried with no evidence that the components are causal.

The role of the "research" component in the larger process of industrial innovation and commercialization of products and creation of jobs is minor. Furthermore, the value of having the research done locally has not been established. The Japanese "innovation machine" proves the opposite. A complex of factors including local ambience, desire of key personnel to settle in the area, availability of appropriate capital and management structure is vastly more important than access to local university research.

INCUBATORS

It is chancy at best for government to put resources into incubators in the hope of economic development. A recent study of Pennsylvania incubators, which is one of the earliest and biggest of the state incubator programs, indicates that "incubators do not add value to tenants above and beyond what non-incubator firms can get from the marketplace outside of incubators."[1]

III. WISCONSIN UNIVERSITY MODELS FOR ASSISTING STATE INDUSTRY

INDUSTRIAL SUPPORT FOR UNIVERSITY RESEARCH: THE CONTEXT OF THE SURVEY

Most research funding for universities comes from the federal government. This creates an imbalance in the national knowledge base skewed toward government priorities (principally military needs, though not in the case of Wisconsin's universities). Thus, in order to remedy this imbalance, many policymakers would like to see industry support university research. For example, one Commerce Department advisory committee noted: "It is also hoped that the resulting increase in university/industry coupling will be viewed by industry for what it could become: significant opportunity to invest people and material resources in an opportunity that in total will be of significant benefit to employees, customers, shareholders, and society--an opportunity that can compete successfully for resources with other investment opportunities available to the industrial community."[2] But, even in 1979, when that was written, it was to beat a dead horse. Twenty years earlier President Eisenhower came into office with the idea that industry should do basic, long-term research, either on their own or with universities. However, in reality, industry was and is rarely interested in "supporting" research, especially basic research unless it is heavily funded by the federal government. They are not interested in investing in bricks and mortar or that elusive "future." Their needs are for quarterly dividends and commercializable products to show the shareholders. Given our economic system, it is unreasonable to expect anything else--as Eisenhower acknowledged by the end of his term of office and others have had to acknowledge since. Thus, faculty have to work against the flow of the U.S. economy in order to initiate consortia and keep them afloat. The following description of Wisconsin engineering faculty initiatives should be placed in that context.

INDUSTRY-"UNIVERSITY" LINKAGES: THE WRONG IDEA?

Although the phrase "university-industry relations" is seen constantly today in education and government publications, much of the effective linkage is, and always has been, between <u>faculty</u> and industry, and only by-the-way with a specially-tailored university structure and industry. Engineering faculty have a long tradition throughout the U.S. of working as problem-solvers for their natural partners, business and industry. From the thirties onward, and strongly in the fifties and sixties, individual corporations sponsored research projects with thousands of faculty. Collective industry groups (the American Petroleum Institute, the Iron and Steel Institute, even the Lead, Zinc and Selenium Institutes) selected from 12-50 faculty in as many institutions to do their research. In the eighties other modes of interaction, particularly consortia, have been added to private consulting, in some cases with state guidance and money. Consortia, too, are primarily linkages between small groups of faculty and their students and industry. Thus, the undefined term, "university"-industry relations creates confusion and sometimes sends policy planners looking in the wrong direction, that is toward setting up elaborate bureaucracies. Knowledge transfer to industry directly from faculty working on problems already of interest to industry is efficient both because it can be market-driven, creating innovations that can move faster into the economy, and because it is unhampered by cumbersome paperwork of the now prevalent "grantsmanship." <u>Such relationships are relevant and effective precisely because they can be guided by market pull</u>.

University administrations do, of course, have a place in all this. They can be sources of encouragement or discouragement to faculty development in this area. So too can newspapers and legislators, the former by the slant given to reporting faculty participation in knowledge transfer to industry and the latter by their oversight and initiatives.

A. RESULTS OF RESEARCH CONSORTIA SURVEYS, Madison

The College of Engineering at Madison houses 25 active centers/consortia linking faculty and industry. Twenty-four of those consortia formed our survey sample. The large number of consortia indicates that there is recognition on both sides that alliances can be useful, and it gives us an idea of quantity. However, we wanted to go beyond that and understand how the consortia function and the quality of the interactions with industry. With that information we were able to compare them with other attempts in the U.S. to implement knowledge transfer between faculty and industry.

To explore the ways that groupings of faculty and industry interact within consortia, we surveyed all of the major consortia in the College of Engineering. The survey questions were designed to provide a picture of the actual workings of faculty-industry relations as represented by consortia. Areas of interest include (1) perceived motivations of industry to join consortia, (2) modes of interaction between consortium partners and specific mechanisms for knowledge transfer from research lab to industry, (3) data on industrial partners, and (4) dollar size of the investment in consortia in Wisconsin engineering education institutions.

As is seen in Figure 1, industry contributed nearly $4 million to research at Madison in 1989. Our first set of questions involves the motivation of industry, as perceived by faculty, to invest in a consortium.

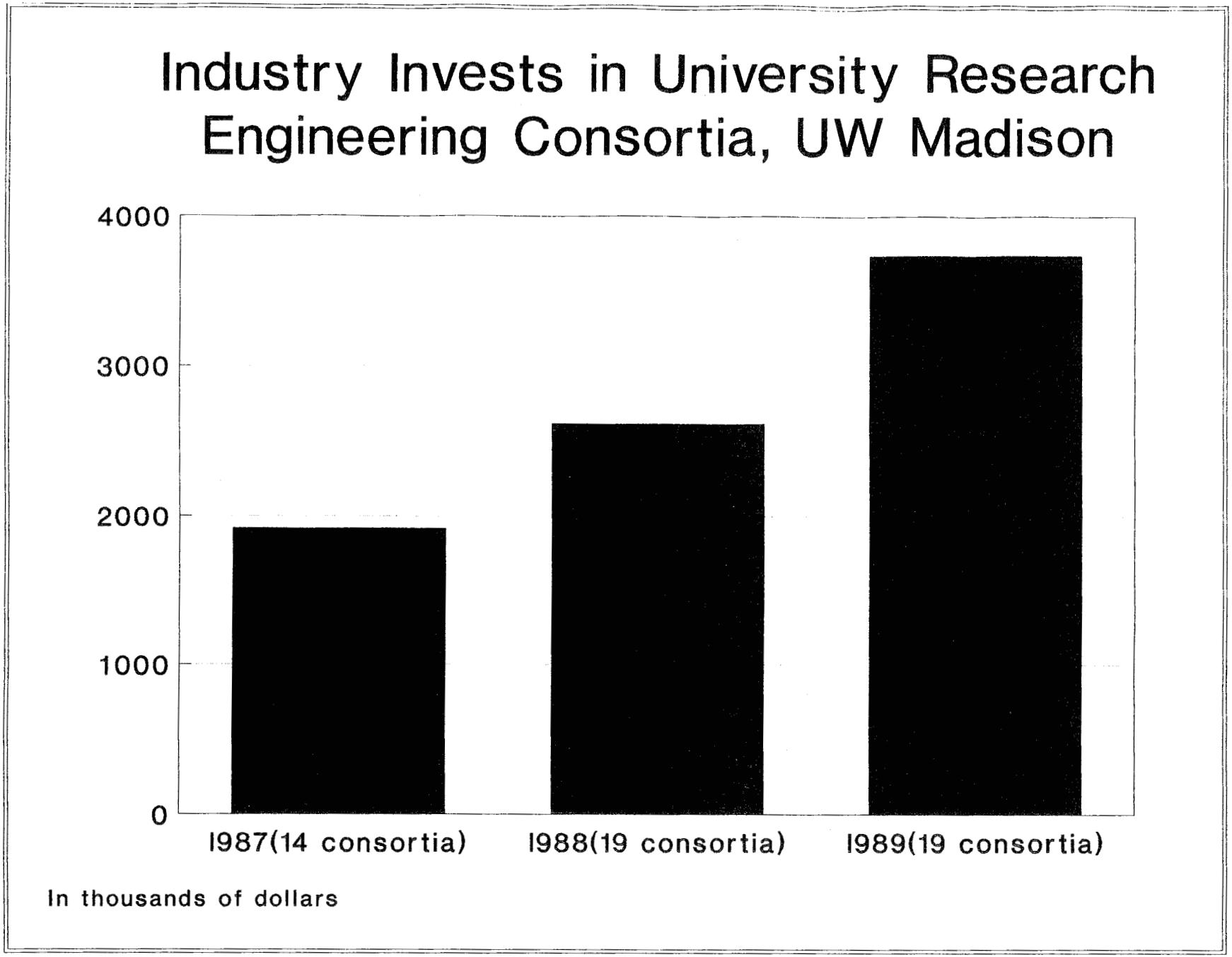
GETTING THE BEST EMPLOYEES

By far the greatest benefit seen for industry from the point of view of the faculty is the recruitment of better personnel. The major mandate of the university has always been to train a work force competent for the times, and industry traditionally has come to them for precisely that. Focusing on industrial problems is an ideal way to give students the training they need.

FACULTY-INDUSTRY CONNECTION: GETTING IN TOUCH

Similar to the way in which faculty and industry link with one another in consulting arrangements, the overwhelming impetus for coupling is individual faculty contacts with industry. Seventy-five percent of all faculty respondents indicate that consortia members are targeted to either a "great extent" or a "very great extent" through previous faculty contacts with companies. Another 44 percent identified companies' historical relationships with the university as also important. Only rarely did companies contact the consortium on their own initiative or because of previous contacts with other university research programs. From what we know of other industry/university alliances, this dependence upon individual faculty contacts is typical. For example, two-thirds of the industries that provide some support to the U.S. Engineering Research Centers (ERCs) report that they had previous contacts with faculty involved in their consortium.[3]

FIGURE 1


Industry Invests in University Research Engineering Consortia, UW Madison
4000
3000
2000
1000
0
1987(14 consortia)
1988(19 consortia)
1989(19 consortia)
In thousands of dollars

WHY HERE: TYPE AND QUALITY OF RESEARCH

In response to why industry is willing to fund their consortia, faculty cited the state-of-the-art research they are doing and the fact that research matches sponsor interests. Ninety-six percent ranked both factors extremely or very important. They also felt that industry values access to up-to-date information in the field of research (25 percent extremely important and 46 percent very important) and access to technical assistance from consortium personnel (25 and 46 percent respectively). Type and quality of research seem to be common criteria used when industry decides to sponsor research at one of the renowned research institutions in the U.S. similar to UW-Madison. For example, comparable questions asked of Engineering Research Center participants rated quality and match of interests as extremely or very important in 88 percent of the cases. This is more or less what one would expect.

The outstanding reputation of faculty in the consortium's areas of interest are, no doubt, a very big calling card. As one researcher at a Wisconsin institution less-highly reputed for research noted, the flip side of this is the difficulty for faculty at less well-known research universities doing parallel work to establish consortia. They do so with much greater odds against them than does Madison.

ECONOMIC BENEFITS TO INDUSTRY?

About one-third of the faculty think that industry is motivated to join them because of the opportunity to develop patentable products. One-third of them think that sponsoring companies will actually derive "great" or "very great" benefits from resulting patentable products. Similarly, faculty estimate of the possibility of commercializable products as an anticipated, real benefit was about the same as for patentable products. Whether the perception of faculty concerning the eventual commercial application of the transferred knowledge is correct or not, the consortia do represent a way to narrow the gap between university and industrial communities. In the final analysis, it will be the responsibility of industry to tap the innovative potential and utilize the new knowledge in new products or processes. In this regard the faculty are certainly much too optimistic.

KEEPING AHEAD

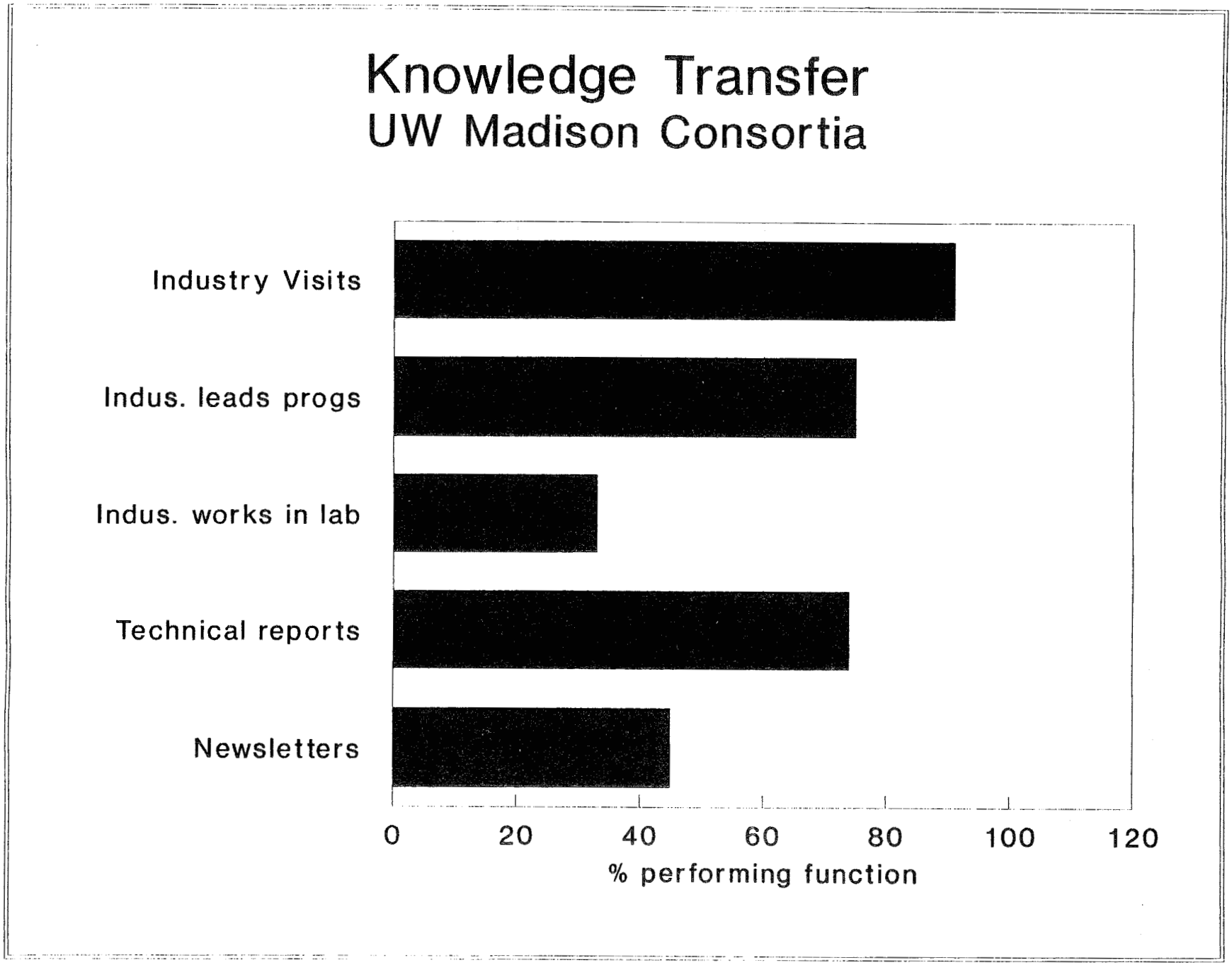
Faculty also perceive that industry will glean ideas for new research opportunities by their participation in the consortium (70 percent "very great" or "great" benefit). This is undoubtedly a reflection of the state-of-the-art nature of the work done in the labs at UW-Madison.

INTERCHANGE OR LETTERS FROM THE IVORY TOWER?

A primary goal of a consortium is knowledge transfer. Industrial partners in consortia do, of course, receive a lot of information about research progress and outcomes in several ways. But what about the value of the information? Is it merely another form of publication of research results? The questionnaires explored this issue, and found some encouraging results (see Figure 2).

Most notable, ninety-one percent of the consortia have held from 1-5 events, such as technical seminars, workshops, and symposia during the past year that industry sponsors attended. At three-fourths of those meetings, industry sponsors helped present information. Thirty percent of the consortia had people from industry lead educational programs, such as courses or seminars. This is an encouraging sign that interchange is taking place and not just dissemination of research results. If consortia are to flourish

FIGURE 2


Knowledge Transfer
UW Madison Consortia
Industry Visits
Indus. leads progs
Indus. works in lab
Technical reports
Newsletters
0
20
40
60
80
100
120
% performing function

(though individual consortia should come and go when research goals are obtained or change), then faculty must have more information as to what is going on inside industry. Without that, they will have a much poorer chance of having a positive impact on innovation in industry and of getting financial support.

Another mechanism for fruitful interchange is for a company's researchers, or other appropriate personnel, to spend time on-site in consortium research laboratories. One-third of the consortia have had from 1-5 industrial research workers spend long periods (minimum one month) in university research groups. If there is a problem here, it is that faculty do not visit industry enough. While consulting may get faculty into the plant, consortia as a general rule do not.

In the past twelve months, seventy-four percent of the consortia issued technical reports on results of research sponsored by industry. Forty-five percent sent out newsletters on center activities. The latter is less useful than actual, in situ, interchange between faculty, students, and industry but can be useful nonetheless.

WHAT'S IN IT FOR WISCONSIN BUSINESS?

For the 1989-90 fiscal year, the 24 consortia in the sample included a total of 206 businesses, 44 percent, or 88, of which are Wisconsin businesses. Only five consortia do not include any Wisconsin businesses in their membership. Of those, two do research in specific industrial processes and are totally funded by out-of-state industry, two are substantially funded by the federal government on targeted technologies, and one has no industrial funding at this time. This is not unusual; that is, in any top-notch research university there will be some research for which the state does not have an industrial match.

Two of the consortia involve only Wisconsin industry, one of those heavily leveraged by federal government contracts.

The majority of consortia provide not only research for Wisconsin industry, but, because of their high reputation, bring in out-of-state partners to increase benefits for Wisconsin partners in the same consortium. This broadens Wisconsin industry's interaction with the relevant community.

KNOCK-ON EFFECT

This study did not tap all faculty/business interactions that result from consortia. But there is a frequently occurring knock-on effect that should be mentioned. Although a business may not have an interest in funding on-going research, they may hear of the consortium and, as a result, make contacts with faculty about specific problems or projects. Many of the faculty receive several phone calls each week from industry. For some callers faculty act as referral service, giving them names of colleagues who would be most appropriate. For other calls, a feasibility study may be in order for a project. Resultant studies are done on a regular basis. For many of these Wisconsin industries, rather than joining the consortium the best investment is contracting for focused projects. In this way they receive some of the benefits of consortia-funded research, personnel and equipment.

SMALL BUSINESS/BIG BUSINESS

The political culture of the U.S., as well as that of Wisconsin, bears an avowed interest in "the little guy" who runs the small business enterprise. Although recent data show that this little guy is not so little--in 1983, 80 percent of all small businesses were owned by house-

holds with assets of $500,000 or more[4] --voices for small business are never absent from the U.S. political scene. For example, political action committees (PACs) representing small business contributed to incumbents during the 1984 U.S. senatorial campaign the same percentage (25%) of all PAC money as did organized labor. Small business has been the recipient of subsidized loans and tax breaks, and is regularly considered for quotas or other small-enterprise "affirmative action" when legislation is written. For example, one-quarter of all state competitive research grant programs are restricted to small business participation, and in 1988 the federal government appropriated $40 million and the states another $8 million for 53 Small Business Development Centers, which oversee more than 500 sub-centers.

The faculty involved in this study are aware of the political disposition to promote small businesses. We examined the consortia for inclusion of small business. We found that the majority of firms (155) that join the engineering consortia employ over 500 people. But, another one-third (51) have between one and five hundred employees and, thus, fall under the "small business" category. Only twelve of those have less than 50 employees, which for most of the public is the image brought to mind when "small business" is used (see Figure 3).

To place this in perspective, one can look at comparable data on the Engineering Research Centers sponsored by the National Science Foundation. (One of the centers in this study, Plasma-Aided Manufacturing, is an Engineering Research Center.) The Wisconsin engineering consortia are in type and quality of research comparable to the Centers. Although the Centers have a special mandate to serve industry and small business, for the latest data available[5] only one-sixth of their industrial partners were small businesses, compared with one-third for the Wisconsin sample. And, since one-half of those Engineering Research Center's small businesses were in a single consortium, the MIT Biotechnology Process Engineering Center[6], Wisconsin small business participation in consortia looks even better.

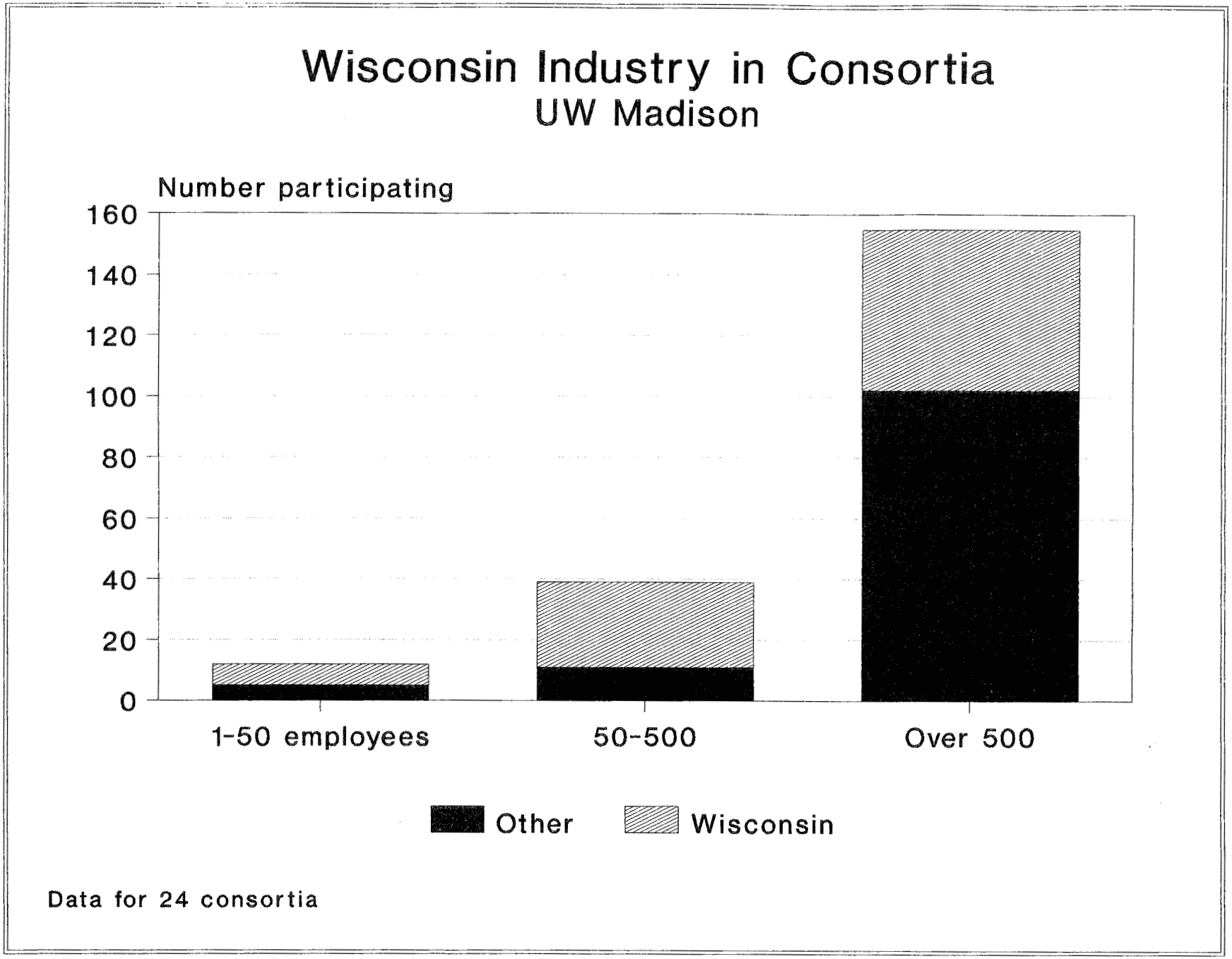
A second comparison in reference to small/large business partners can be made using the National Science Foundation's University-Industry Cooperative Research Centers, for which we have extensive evaluation. Although these centers have been successful in that they have promoted industry/university joint efforts and produced non-federal research and development investment at a ratio of 7:1, they have not reached small business. The preponderance of business involved in the Science Foundation's centers are Fortune 500 companies.

The Madison success in attracting small business is certainly impressive in relative terms. This is an encouraging sign that university faculty and a wide segment of Wisconsin industries are touching base with one another.

B. DAIRY CENTER, MADISON

Wisconsin ranks high in the U.S. in farm marketings, and dairy products make up a large portion of that total. Although this study focuses mainly on university engineering units and their partnerships with industry, the Center for Dairy Research at Madison was included in the study in order to sample at least one area of agricultural technology transfer from university to industry.

FIGURE 3


Wisconsin Industry in Consortia
UW Madison
Number participating
160
140
120
100
80
60
40
20
0
1-50 employees
50-500
Over 500
Other
Wisconsin
Data for 24 consortia

A READY-MADE CONSORTIUM

Like the engineering consortia, this Center was begun on the initiative of a faculty member. But, because of the way the dairy industry is structured, there was a ready-made university partner, the Wisconsin Milk Marketing Board. Norman F. Olson, professor in the College of Agricultural and Life Sciences, worked with the Board to form the Dairy Center in 1986. It is now one of six national dairy foods research centers and receives a little less than one-third of its funding from the National Dairy Promotion and Research Board. The Center's aim is to improve the economic vitality of the dairy industry through "research and information transfer."

The Center publishes several newsletters and readable technical reports in addition to holding conferences, seminars and workshops which reach to all levels of the dairy industry. *UW Dairy Pipeline* is put out through the joint efforts of the Center and University of Wisconsin-Extension. The Milk Marketing Board also aids in disseminating information through publishing and widely circulating the Center's research findings.

A large number of industry personnel come to the lab to exchange ideas about needs, appropriate research, and research findings. In particular the research and development quality control and marketing research personnel interact with the Dairy Center, and this signals the fact that research is closely linked with market needs and information flows two ways.

KNOCK-ON EFFECT

Because of their link with the Dairy Center, the Marketing Board is involved with the university in an increasing number of ways, for example strategic planning committees. The interaction of the Center with industry has meant a multiplier effect, bringing representatives of the dominant area of the Wisconsin market products into increasingly active involvement with the university.

KNOWLEDGE TRANSFER BEGINS WITH INDUSTRY-RELEVANT RESEARCH

The respondents interviewed at the Marketing Board noted that it is not merely the information, transferred through seminars, publications, conversations and so forth, but the expertise generated among Wisconsin researchers through the research process that is valuable to the industry. They observed that researchers develop the expertise to make the knowledge work. This is rare in research consortia. Probably the closest that engineering researchers in our sample come to such a working relation is with the project-focused work of the MSOE faculty or small projects done for individual firms. In sum, a whole information system is developed in the Center for Dairy Research that includes the researchers who have the ability to transfer that knowledge successfully to the "shop floor".

The Dairy Center does not do much project work for the industry, partly because they do not want to compete with private consultants. Even so, they have more requests than they can handle for project work.

The applied nature of the Dairy Center's research can be easily seen from the list of their research topics:

- Improve flavor of reduced-sodium and reduced-fat cheese.
- Evaluate manufacture of cheese made from milk pasteurized at high temperatures.
- Extract cholesterol from milkfat.

•Develop new dairy food using added fiber and calcium.
•Study economic benefits of increasing milk quality used for cheesemaking in Wisconsin.
•Investigate properties of milkfat fractions that my be used as food ingredients.
•Study fate of Listeria during pasteurization and cheesemaking.
•Improve methods of detecting pathogens in dairy products.

This problem-focused research has borne fruit for the dairy industry and will no doubt continue to do so. For example, the development of manufacturing and packaging processes of cheese to control calcium lactate crystallization is estimated to save 4 million dollars per year for Wisconsin and 15 million dollars per year nationally.

LOST CHANCES

Funding from Wisconsin dairy farmers through the Marketing Board has been steadily rising over the Dairy Center's four years of existence, and the Board intends to continue to support it. In fact, if the Center had sufficient personnel, it would be able to sponsor a substantially greater amount of research, especially in the cheese area.

Currently Marketing Board money flows to out-of-state institutions for additional research that cannot be handled by the Center with present staffing. The benefit of doing more research within the state would be not merely the immediate cash benefit but also the expertise for successful knowledge transfer developed among researchers housed within the state.

Currently Wisconsin is the major culture and enzyme supplier to the U.S. dairy industry; of the total of six suppliers, only one small supplier is located outside the state. However, the five in-state companies are now all owned by foreign firms and, in general, foreign firms are investing in Wisconsin dairy industry. They are more technically oriented than previous Wisconsin owners, and it will help to keep them here if the university is able to offer sufficient personnel and space for innovative research. The fact that the Center is linking with dairy researchers internationally, through the "Worldwide Information and Technology Exchange Program," will also help in this regard.

NEW CROSS-FERTILIZATION

Recently the Center for Dairy Research has started to hire consultants (one this past year), and the hope is to do more in this regard. Recently-retired individuals from business or government jobs related to the industry can offer younger faculty and staff the benefit of their experience and help allay the personnel shortage. This is an astute move that may have very positive effects on industry-university linkages.

As in other centers, there is an unfortunate trend to applaud the faculty researcher's efforts in outreach to industry but ignore the need for administrative personnel as support. In the Dairy Center, the siphoning off of the director's time into low-level paper work is a poor use of university personnel.

C. INDUSTRY-UNIVERSITY RELATIONS: MARQUETTE, UW-MILWAUKEE, and MILWAUKEE SCHOOL OF ENGINEERING

Because consortia are a minor part of the Marquette and UW-Milwaukee engineering configuration of university-industry cooperation, the overall descriptions below are more useful in evaluating their endeavors than looking at those few consortia.

THE MILWAUKEE ENGINEERING CONSORTIUM

The three Milwaukee engineering schools formed an engineering consortium in 1988 to increase and coordinate their contacts with industry. This is a laudable regional effort across institutional boundaries. The Milwaukee Engineering Consortium can facilitate networking to give complimentary advice on any engineering problems that a company may wish addressed. Together they offer a wide range of expertise and facilities that are not otherwise available to industry. A major element in their agenda is to produce graduates attuned to industry problems. At the graduate level, they use annual membership fees paid by participating companies to support engineering graduate students. A company is given the option of selecting students from prescreened finalists from any of the three universities. The students then work on a company problem and the project becomes the student's master's degree or Ph.D. thesis.

PIRATING TIME FOR OUTREACH TO INDUSTRY

The Milwaukee Engineering Consortium is especially noteworthy as an example of new coalitions of institutions that are being built around the country, especially by institutions that have not been the recipients of big federal bucks. Innovative university administrators pool resources and enhance visibility to industry. Like most of the initiatives for university-industry cooperation in Wisconsin's education institutions, this one has been done by a few faculty or administrators with only token funding ($20,000 per year). Essentially, time is pirated from other education activities to serve industry. For example, the dean and associate dean at Marquette have contacted approximately 150 businesses and industries by phone to talk about possibilities, as does each of the Consortium schools. So that outreach does not become dysfunctional for other aspects of the university mission, administrative support is crucial (see section under "Centers" also).

MARQUETTE UNIVERSITY

Currently, Marquette has faculty working on agricultural research, electronics, environment, fluid systems, manufacturing systems, medical technology, and multiple-use applied technology programs. The types of links with industries that promote use of this research cover a healthy variety.

Testing is one area of interaction. For example, in water quality, test work is done for municipalities and companies for fees, which amount to $70,000-$80,000 for the University.

A second mode of interaction is within continuing education. Marquette, along with UW-Milwaukee, serves the electrical power industry, and has done so for several years. It offers short courses every 3-4 months for employees in the industry. Interestingly, the faculty for each seminar are drawn from both technical engineers and university professors. As pointed out in reference to consortia, these truly joint activities are the most useful form of cooperation because they promote a two-way flow of information. The faculty member in charge of the power seminars sees seminars as a way of introducing faculty to industry and getting faculty interested in industry problems and further contacts.

Thirdly, Marquette does new product development with manufacturing firms. These are funded research projects and occur predominantly in mechanical and industrial, electrical, computer and biomedical, and civil engineering. The financial arrangements for this mode of university/industry interaction, as well as testing, are facilitated through Marquette's Engineering Research Foundation.

Fourth, as has been traditional in all engineering schools, faculty act as consultants. An estimated 40 percent of the faculty have done consulting. Fees may be arranged either by individuals involved or fall within the administration of the Engineering Research Foundation. It is obvious that among the faculty, there are only a few individuals who are intensely active in promoting industry-university cooperation and in integrating that into the

teaching mission. If they are supported, they may succeed in increasing the interest of other faculty. However, Marquette needs to make sure that faculty reward systems incorporate this activity.

A fifth link that Marquette fosters with industry is integrated into the teaching mandate of the University, somewhat like MSOE. Marquette engineering students do a design course in the senior year, in which they work in interdisciplinary teams on a design project.

Sometimes business students will be engaged in the project, too; the benefit of working in such teams as preparation for work in the economy is obvious. Projects are often done for industry, and constructing the curriculum in this fashion puts both faculty and students in contact with industry. Additionally, the emphasis on problem-solving within a small project means that faculty and students can be responsive to small and midsize firms.

STRENGTH IN NUMBERS

Formation of consortia at Marquette is very limited. Of the three consortia heads who filled out our questionnaire, two have one industrial member each. Those industries partially match either state or federal funding, and the consortia probably would not exist without government funding. A third faculty member, who has been trying to organize a consortium through his own effort, has found the task an extremely frustrating one. He observes that few industries are willing to gamble on high-tech processes, and established companies prefer to go to big schools like UW-Madison. This, no doubt, is not a unique experience, but reflects the general difficulties of starting up consortia. Because of these difficulties, the efforts of the three Milwaukee schools to combine, for example in the relatively new Materials Science and Technology Center, will probably be the major way that industrial interest and participation will be forthcoming for them. It will also be the only way to be competitive for federal funds.

UNIVERSITY OF WISCONSIN-MILWAUKEE

As is the case at Marquette, engineering consortia are few in number at UW-Milwaukee. Questionnaires for the study were sent to the six consortia identified by the Associate Dean of Engineering and the Office of Innovation and Technology Transfer. Five replies were received and the four leaders of those consortia were interviewed. The fields of innovation involved are waterjet cutting technology, liquid metal combustion, thin film research, processing and characterization of composite materials, and foundry and solidification processing. The latter two have common funding, including Office of Naval Research funding. Most of the industry support comes from large companies, both Wisconsin-based and national, and in the five consortia the largest membership is approximately six. A few small, local companies contribute equipment and materials, but they are not consortia members. As was noted by Marquette faculty also, small business is less likely to find support of research of any value to them; they value most the graduate engineers, who are potential employees.

In order to maximize its academic success UW-Milwaukee has developed "centers of excellence" in selected areas. However, although this can provide added visibility, the establishment of successful consortia will depend upon individual faculty members who

can provide the necessary match between what their research interests are and the needs of industry. An area of academic excellence, may remain irrelevant to Wisconsin industry.

MILWAUKEE SCHOOL OF ENGINEERING

UW-Milwaukee depends heavily on government grants; the highest industry-government funding ratio for a UW-Milwaukee consortium is approximately 50-50. MSOE, on the other hand, depends almost entirely on industry for its project/research work. The history of MSOE in industry-university cooperation is a long and flourishing one, as we will see below.

PRIVATE CONSULTING

As mentioned earlier, engineering faculty have a long tradition of working with industry. To explore the level and nature of faculty interaction with industry in non-consortia configurations, we used MSOE as a case study. Data on consulting was obtained directly from faculty; other data is from Thomas Davis, Senior Vice President of Academics and Dean of the Faculty.

As a general rule in the U.S., consulting work has been the prerogative of all faculty, but often university administrations do not actively encourage consulting. However, MSOE views consulting as a part of faculty development. MSOE does not have a tenure system but, rather, a professional "growth and development" requirement for contract renewal. They actively encourage consulting so that faculty will form contacts with industry and bring experience back from industry to enhance the training of their students. Last year 50 percent of the faculty did some project with industry and 75 to 80 percent have done consulting work. This Wisconsin model, described in detail below, is one from which other institutions in the U.S. may well learn.

SURVEY DATA

Of approximately 45 full-time engineering and science faculty, 31 faculty responded to a questionnaire about consulting. To ascertain the level of activity, we asked faculty members how many firms they had done private consulting for in the past three years. The average was 3.74 different firms; the highest number was 15, and only one faculty member had done no consulting at all. Even if we assume that none of the faculty members who did not respond do consulting, this activity represents considerable knowledge transfer to industry involving at least three-fifths of the MSOE faculty.

MSOE encourages faculty to do applied research with companies at plant sites rather than on campus. Ninety-eight percent of the consulting done by faculty is done within the company. This facilitates learning on the part of the company employees and also serves to familiarize faculty with what is happening in industry. Through personal interaction, technical knowledge exchange and understanding of needs is enhanced in areas beyond a specific project.

Aside from private consulting, faculty have a variety of other working relationships with industry, averaging 3.71 different firms for each faculty member for the past three years. One faculty member worked with 30 firms in three years.

INTEGRATING INDUSTRY SPONSORSHIP AND EDUCATION

In addition to consulting, over 100 industrially-sponsored research projects are done annually at MSOE. These are strictly industrially-sponsored, applied research projects and

are in addition to student and class projects. Sponsorship for the 100 Applied Technology Center projects will amount to about $550,000 in 1989-90.

The Applied Technology Center is an umbrella structure that serves business and industry, and it includes students who are, after all, the primary university product for industry. Each year dozens of student projects are done for no charge to industry under the Center in response to industrial needs.

Industry returns again and again with 40-60 projects per year for MSOE students. This is certainly a measure of the usefulness and the success of MSOE in integrating the education process with assistance to Wisconsin industry. In the process, the institution is able to fulfill the accreditation board's requirement of a capstone engineering design course. This is relevant engineering education, if there ever was.

ON A ROLL

Many MSOE projects with industry are seedbeds for continuing university-industry cooperation. Two-thirds of the faculty have worked with firms that have returned to them for additional projects, some for several projects. The specific example of MSOE aside, this kind of proven performance criterion, wherever found in Wisconsin education institutions, becomes crucial to successful state planning, as we note in the concluding section on matching grants.

EVERYBODY WINS

It is hard for faculty to quantify the ideas that reach the classroom from their experience on the shop floor, but consulting with industry undoubtedly becomes part of the teaching process. Certainly the spin-off into teaching from both consulting and applied research done under the Applied Technology Center is constant and substantial. For example, projects to develop methods using lasers to measure the effects of temperature on the contraction/expansion of objects have been integrated into MSOE curriculum. These concepts, called holographic interferometry, are currently being taught in a physics elective.

Coupling with industry continues and improves the training of students for the work force and aids industry in recruitment. For example, several years ago MSOE was approached by a company to develop a solid-state control system for emergency generators. The design was completed by a senior electrical engineering student, produced and sold commercially. The industry involved hired the student when he graduated. The usefulness for recruitment of these linkages is viewed by industry as a primary benefit to them. In the General Accounting Office survey of industrial partners of Engineering Research Centers, they found that better personnel recruitment was listed as one of the two major, tangible benefits to industry.[7]

UNIVERSITY ADMINISTRATION INITIATIVES

Although a research job well done is the best advertisement, administrations in Wisconsin's universities have set up some useful structures to facilitate faculty-industry interactions, which we describe in various sections of the report. But those structures operate mainly, as they should, as referral services. All of our respondents agree that administrative efforts work best when administration is only a facilitator and exits the relationship between faculty and industrial partner as soon as possible.

In 1981 MSOE set up an Applied Technology Center, which provides assistance to companies through several modes of operation. The Center makes appropriate referrals to companies that wish to sponsor projects that are best undertaken by individual faculty members. But it also transfers basic research and works on new technology development for industry through its applied research programs, student projects and class projects, as mentioned above. These projects can be of direct benefit to the economy, for example in aiding business and industry in the application of the latest technology to manufacturing processes. One firm has 16 completed projects done by MSOE and has 9 active projects.

We asked MSOE faculty about their work through the Applied Technology Center. Fifty percent have worked through both the Center and done their own consulting work. Another 10% have worked only through the Center; 40 percent have consulted on their own only. When asked how the initial contacts were made, the two major avenues were referral by another colleague and referral by the Center or other institutional mechanisms at the school itself. The immediacy and usefulness of this MSOE model to the people of Wisconsin is obvious from the funding configuration: less than 5 percent of MSOE funding for research comes from government sources and the bulk comes from industrial partners. They serve mostly Wisconsin and, beyond that, mainly the Midwest. This could be a national model for sustainable relations between similar teaching institutions and industry. It is, however, to a large degree, dependent upon location in the Milwaukee metropolitan area. Not every institution that is primarily a teaching institution can be expected to find MSOE's success in forging industrial links. UW-Platteville, for example, would be greatly handicapped in trying to emulate the MSOE model since it is not in a metropolitan area.

Marquette is in a different position than MSOE since it does not have such a strong tradition of project work with industry. However, the Marquette Engineering Research Foundation was formed three years ago as a part of an aggressive outreach to industry. In the last two years approximately 20 projects have been undertaken. In institutions across the country where faculty interaction with industry has been sparse, such outreach initiatives on the part of university administration are necessary to make industry aware of opportunities and to expose faculty to opportunities.

D. SPECIAL OFFICES FOR LINKING UNIVERSITY RESEARCH AND INDUSTRY

The Office of Industrial Research and Technology Transfer in Milwaukee, the University-Industry Research Program in Madison, and the Technology Transfer Office of the Medical College of Wisconsin all seek to link university to industry/business in Wisconsin. The Medical College and the Office of Technology Transfer have as one of their goals the identification of intellectual property and licensing. The Wisconsin Alumni Research Foundation does this at Madison, and the University-Industry Research Program operates as a referral service and a catalyst to put faculty and business together. Since each of the offices operates for somewhat different ends, they will be discussed separately.

1. UNIVERSITY-INDUSTRY RESEARCH PROGRAM, MADISON

Twenty-five years ago, the National Science Foundation funded a science-writing unit at UW-Madison, and from that beginning the University-Industry Research Program emerged to network university and industry research interests. The informational/public relations aspect of the Research Program is still its primary function. It is a part of the Graduate School, and works in close cooperation with the College of Engineering Information Services Division in Wendt Library.

THE UNIVERSITY YELLOW PAGES

The University-Industry Research Program offers referral services, essentially spreading information about how to find information. It works to identify researchers with specific expertise needed by business and industry, to locate specialized laboratories and equipment, to network business with university people involved in production of innovative knowledge, and to obtain scientific and technical information upon request. The latter is primarily handled by the Information Services Division of the Wendt Engineering Library. The Division can provide users with information from 400 national data banks, from a complete collection of U.S. patents, and the holdings of the UW-Madison library system. It receives over 20,000 calls annually. This technical portion of the referral system is self-supporting, deriving its income from users. The Research Program, however, is a line item in the State budget.

The Research Program's referral function depends on a wide knowledge of the configuration of faculty research, that is, knowing who is doing what. The fact that the individuals who head the unit and the eight associate directors, who work with them, have long-time experience in the university and know it exceedingly well, lends an important expertise for the unit. A computer database of research interests is maintained, but, given the size and constant development of research at the University, the database is in need of being updated. This should be an obvious priority for continued funding.

In regard to referral services, the Research Program is willing to introduce industry to UW-Madison's research consortia. However, the vast majority of these consortia are begun by faculty, and the business network attached to consortia usually brings the possibility of joining to the attention of all interested parties. Thus, the Program's function in this area is, and will probably remain, minimal.

Although the University Research Park is mentioned in the Program's brochure, this is a separate endeavor, which the Program advertises when possible. Perhaps as the Park develops, the Research Program will be useful in other ways also. The assistant director of University-Industry Research currently serves on the Research Park advisory committee.

WHAT THE CONSUMER THINKS ABOUT UNIVERSITY-INDUSTRY RESEARCH PROGRAM

A sample of individuals requesting information during six months in 1989 was from a list provided to us by University-Industry Research. The sample excluded requests merely for publications and calls from academic sources, which comprised about 30 percent of the total sample for that time period. Those who call the Program find the services provided helpful. Most of them have called more than once. The size of the firms vary from start-ups to large (over 500 employees) and long-established businesses. The sample was predominantly manufacturing, in a wide variety of products, but also included marketing as well as government.

University-Industry Research also does numerous company briefings: 15 in 1989, 15 in 1988, 8 in 1987 and 4 in 1986. Except for one, each company was included only once. Briefings are geared to give company representatives an overview of all the research areas that might prove useful to that particular firm. Because they are in the nature of overviews, interchange is predominantly general at that point, in comparison to referral calls which may be problem-focused. To give an example, one briefing for Cray Research, Inc., included talks from 21 faculty and administrative staff from a total of 15 departments,

consortia, or other units. Eleven Cray employees were in attendance. In essence this kind of briefing is an introduction to the university and to personnel that industry may wish to call upon. The information conveyed is at a general level, similar to that found in various brochures from consortia and departments. The Research Program might do evaluations to determine whether this considerable investment in high-powered research faculty time has been useful to the companies. In the course of interviews on other topics, we heard the complaint that this was too general to be useful as well as that faculty arrive thinking they are to speak about one thing to find that it is irrelevant to the company.

ECONOMIC DEVELOPMENT

The University-Industry Research Program also does some work in conjunction with the Department of Development in assisting companies in obtaining research funds. Specifically, the Research Program does grant reading, writing, and review. Their expertise in grant writing is useful in helping clients for Small Business Innovation Research, referred by the Department of Development, as well as those interested in other Department initiatives. An illustration of this activity is their work with Rustoleum, which led to a Technology Development Grant. They have provided staff and documentation to three recent Governor's Overseas Trade Missions. University-Industry Research has also been a major participant and planner in Innovation Forum and Venture Fairs. The study does not attempt to evaluate their efforts in these particular activities or whether they are appropriate as an arm of the University of Wisconsin Graduate School.

A LOT OF UNKNOWNS

Although University-Industry Research was helpful in describing their program and giving us examples of their activities, it is difficult to compare it to similar organizations in other states because the Research Program does not collect client evaluations or keep detailed records that would produce comparable statistics. It would be of use to the organization itself to have the capacity to keep such records. To give an example of data collection in a similar unit, Pennsylvania Technical Assistance Program (PENNTAP) is relevant. PENNTAP was started at about the same time (1965) as University-Industry Research and has kept data for 18 of the years since then. Thus, for PENNTAP one can obtain public information on several aspects of their activity: the categories of technical problems addressed and the relative frequency of each, the change of focus of technical problems over time, the geographical distribution of their users by state development region, and many other useful classifications such as dollar benefits to users (as reported by users), distribution of dollar benefits by year and type of organization, users by size of business, private/public, start-up/established firm, and so forth. PENNTAP has been given approximately seven million dollars in the last 17 years to run their information service. It is a joint venture between Penn State and the state, but in serving Pennsylvania business it is not limited to the university for sources of information but also uses industry, private consultants, government laboratories, associations, and the like.

There is a feeling of fuzziness about the use of University-Industry Research among Wisconsin business. Why this should be so after 25 years of operation is unclear. But, as one entrepreneur in high tech, and a multiple user of the Program's services, noted in a report to the Governor's Small Business Conference in July 1988, the resources of the University System are sometimes referred to as the best kept secret in town even though the "university community is poised and ready to help."[8] The businessman quoted has found the Program very helpful but observes that the University needs to increase the visibility of its access points for business, and that business, in their turn, must aggressively use that access.

2. WISCONSIN ALUMNI RESEARCH FOUNDATION

The Wisconsin Alumni Research Foundation stands on its own merits as a successful patenting and licensing endeavor. It has targeted certain areas as what it considers--and has proven--sound investment. This means, of course, that it does not serve every research area of the university equally. There is no comparative study of the efforts of U.S. universities in patenting and licensing that has sufficient financial data to evaluate whether it is generally remunerative to use university resources to pursue patents. Fragmentary evidence seems to indicate that those universities that make substantial money with patents do so because of one or two big winners. The Wisconsin Alumni Research Foundation and Stanford have both done well, in the former case due to the vitamin A patent, plus 8 or 9 other lucrative patents, and in the latter mainly due to patenting birth-control technology. Special patenting and licensing units designed to serve areas of research that the Foundation chooses not to concentrate upon might be set up. But, bearing in mind the financially-marginal nature of most university patent offices, to do so would likely be a poor investment in resources. Further, as the people at the Foundation indicate, unless universities have a patent protection unit, the patenting endeavor will be of little use. But, to provide that protection requires a large investment, one that would sink the many university patent offices that are merely holding their head above water. We have had verbal reports from knowledgeable sources that very few universities are at present realizing income above the costs of their patenting operation. Since the Foundation, whatever its limitations, is very successful in what it is doing now, any initiatives in this area should be undertaken with great care.

In our exploration of consortia at UW-Madison and talking with the engineering faculty involved, they did not find the Foundation particularly useful for either patenting or licensing. The problem with regard to licensing in new fields was that Foundation personnel are not familiar enough with industry to do the job. To do so would, indeed, take a large team of technically trained, industrially-linked personnel. The Foundation has obviously decided against this, and runs its office with a very small staff specializing in bio- and health-related fields.

3. OFFICE OF RESEARCH, INNOVATION, AND TECHNOLOGY TRANSFER (UW-MILWAUKEE)

The Office of Research, Innovation, and Technology Transfer, which is part of the Graduate School at UW-Milwaukee, has been in existence for only a few years. After an initial grant from the Technology Development Fund, it is now funded on a continuing basis through the legislature. Its mandated activities are concentrated in three areas: collaborative research and development programs, technology transfer, and consulting agreements.

GETTING THE BALL ROLLING

Like the University-Industry Research Program, it provides referral service for requests from business. But it contrasts with the Program in several ways. The Office of Technology's emphasis is on stimulating faculty interest for linkages with industry, identifying problems of industry, and, then, matching the two. They see clearly the misnomer, mentioned in another section of this study, of "university-industry" relations, and look directly to the faculty as the university element in such alliances. Working with a much smaller faculty than is at Madison, the Office of Technology also acts as an ongoing support system for faculty in a wide variety of activities. For example, they facilitate grants, give advice for legal paperwork, provide lists of potential industrial contacts, set up

meetings, and then continue to nurture those relationships. Their work with companies, as well as faculty, is personalized, geared to identifying specific areas of company need and then bringing faculty into the interchange. In this regard, they operate more like PENNTAP than University-Industry Research Program. Unlike University-Industry Research, they do not do company briefings or seminars of a general nature but focus directly on knowledge transfer.

In Madison, commercialization and patenting are handled by the Wisconsin Alumni Research Foundation and other outreach by University-Industry Research, but the Office of Technology combines the two. Further, it not only acts in patenting matters but promotes patenting, unlike the Wisconsin Alumni Research Foundation, which has more faculty interest in patenting than it can handle. The Office of Technology's director has legal training and acts as the "technical" specialist in legal agreements involving knowledge transfer.

4. THE MEDICAL COLLEGE OF WISCONSIN RESEARCH FOUNDATION

The Medical College of Wisconsin has its own organizations, the MCW Research Foundation, set up to initiate relations with business and industry in order to accelerate the conversion of College faculty research results and findings into commercial applications. The Research Foundation originated because it was thought that an office with a specific mandate to connect the potential of the institution to the community would be the fastest way to get technology into the marketplace. In addition, in 1982 a for-profit subsidiary, Research and Resources, Inc., was established by the College to provide research consulting services and equipment to industry and to help industry develop commercially-applicable ideas originating outside the university for transfer to the marketplace.

From its beginnings in 1984, the work of the Research Foundation and Research and Resources, Inc., has resulted in 28 patents applied for or granted, 7 new companies, and 11 new products. This was accomplished with the labor-intensive effort of the Vice President of the Foundation, Don Westermann. There are two aspects in the nature of at least some of the research at the College that make it a likely site from which true technology transfer can be coaxed. First, the research of a medical college is often focused on specific needs of health care. Thus, from its inception, such research is geared to at least the beginning of the long road to eventual commercialization. As mentioned in another section of this report, economists argue that an understanding of the needs of future users at a very early stage of research and development is helpful to successful application. Secondly, the marketplace for advances in health care is booming. All of America seems to want an investment in health. Instrumentation innovation is fueled by the desire for non-invasive medical technologies.

Westermann facilitates the entire process of transfer from research to product, that is, he works from the early point of identifying the intellectual property as a possible candidate for transfer to finding a match with the right entrepreneur, venture capital, etc. Part of his success stems from the fact that he recognizes that, in the end, transfer is best accomplished with constant dialogue between researchers and business. Making and stimulating matches between the right researchers and the right entrepreneurs is a labor-intensive effort, however. As one commentator noted, in addition to finding qualified executives, accounting services, consultants, venture capital finance and other expertise, the Foundation does "extensive hand-holding through the company development process."[9]

A recent spin-off company, SORBA, provides an excellent example of the careful and very substantial effort that it takes to facilitate technology transfer even under some of the best conditions. The final product of SORBA is an instrument to measure electrical signals of the heart. It had its inception in the innovative instrumentation requirements of a physiologist who was doing research on the electrical characteristics of the heart. Even though this research problem was reduced to instrumentation that was promising as commercializable intellectual property, it was still far from commercialization.

The Foundation was able to locate a perfect match in an entrepreneur--an engineer who had been in medical technology for 25 years, had co-designed a medical technology himself, and had excellent business management skills. Following a six-month market investigation, the project showed commercial promise and, through the Foundation, collaboration between the entrepreneur and the scientists was initiated. In barely a year, the technology emerged into a prototype, with all the R & D completed. That it could be brought to product in such a short time is illustrative of the user-focused nature, as mentioned above, that can occur in this type of research.

The entrepreneur was able to expeditiously get permission for clinical trials and the cooperation of top hospitals in the country for those trials. At that point, only the venture capital for producing the instruments to send out for testing was missing. But, despite the extensive work of over 15 years on the technology and method, despite the research being documented in numerous articles in scientific journals, and with a market that is looking for non-invasive technologies and imaging technics, investors did not beat down the door to SORBA's venture.

The problem of getting venture capital was, in this case, due to cultural attributes of both business and science. On the one hand, the scientists who knew about the development, have scientists' reticence about recommending anything before all the evidence is in, including clinical trials. Investors, on the other hand, take the least note of skepticism as a negative signal. The situation that impeded SORBA's capitalization is not unusual in medical research. Skepticism is well ensconced as a part of the interpersonal and scientific network of innovation in the medical profession, and this will not be reassuring to investors.

LIMITED APPLICATION FOR THIS MODEL OF TECHNOLOGY TRANSFER

It is doubtful that the model provided by the Medical College of Wisconsin's Research Foundation is transferable to all other research universities. This is due to the very characteristics that account for its success. First, unlike other research, the research of the College is often close to market needs. But, even more importantly, the administrative effort that is put into technology transfer by this office is so intensive that its cost would be prohibitive if such a structure were to be entertained for all, or even many, of the research laboratories of Wisconsin's education institutions. To set up a technology transfer operation in the U.S. requires around $100 million, while royalties on patents usually yield about $3,000 per million dollars of research except for the rare, big winners. The lesson to be learned from the Foundation is just how extensive, multifaceted and costly the job of technology transfer is.

IV. STATE PROGRAMS IN SCIENCE AND TECHNOLOGY

A. COMPETITIVE RESEARCH GRANTS

1. THE NATIONAL SCENE

Research grant programs are among the initiatives states have taken to support technological innovation through the universities. Grants comprise approximately 25 percent of all state funding for science and technology-development programs. (This excludes grants internal to state university systems themselves.) In terms of state dollar commitments, grant programs are second only to centers of excellence. But, since much of the funding for centers was used to build infrastructure, grant monies are the largest segment of state programs committed directly to innovation research.

Since most research grant programs linked to state science and technology boards, commissions, and the like, have begun since 1985, impact evaluation studies are generally not available yet. Goals for the programs vary. Some of them were initiated as alternate ways of funding universities and building research capacity in fields that were lackluster in particular states. Those were usually not competitive. In other states, the emphasis is more directly on economic development.

WHERE THE BETS ARE PLACED

Robert Noyce, founder and chairman of Intel and president of Sematech (until his recent death), said of the U.S. approach to science policy, "The religious devotees of laissez faire and free trade have met the devotees of a managed economy and managed trade, and they have been defeated." This appears to be even more true of research policy. Even where U.S. science policy was not altogether laissez faire, it operated on a diversification principle--place your bets on everything you can, and some will be winners. However, with their limited budgets, states do not have the same luxury. They have had to target research areas that at least seem closely and immediately linked to innovations that will pay off. As a result, a definite set of technologies has emerged as state targets for grant programs. From a sample of 25 state grants programs the emphases that emerge are, in descending order of frequency: biotechnology, computer science and software development, biomedical, manufacturing, agriculture, microelectronics, energy, and telecommunications (see Figure 4).[10] By far the largest emphasis for state grants is on biotechnology, which also has emerged in Wisconsin as a target of State funding.

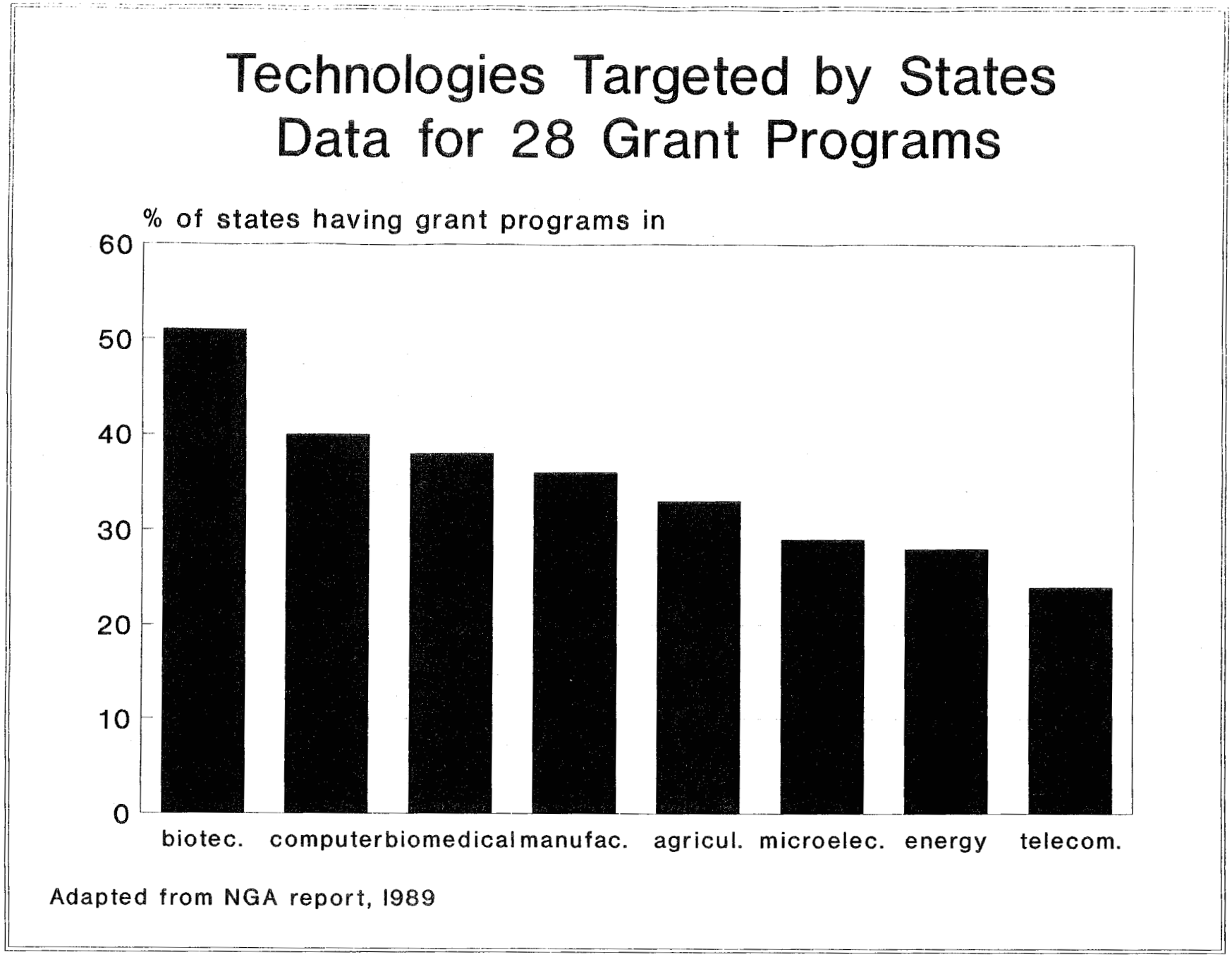
Excluding the grant programs that contain Small Business Innovation Research, 65 percent of state grant programs in the most comprehensive study done to date target specific technologies.[11] Seventy-six percent of those limit eligibility for application to their targeted technologies.

HOW THE BETS ARE PLACED

If the goal is economic development, whatever the targeted technologies, there are several questions to be asked. Who can effectively evaluate applications? Who should be eligible? Should match money be required? Should funds be allocated only to state industry?

One question relevant to successful design of a state competitive grant program is how to identify the winners. States have answered in several ways, from having experts review proposals to having a small program staff make the decisions. The proposal review and

FIGURE 4


Technologies Targeted by States
Data for 28 Grant Programs
% of states having grant programs in
60
50
40
30
20
10
0
biotec.
computer
biomedical
manufac.
agricul.
microelec.
energy
telecom.
Adapted from NGA report, 1989

selection process should be geared to the goals of the program. If a goal is research that can be applied outside the laboratory, then, at a logical minimum industry and researchers should be involved in review. Several states have only internal means of proposal review and selection, that is, review by state agency staff and/or agency subcommittee. One drawback of this procedure is lack of relevant expertise, which allows for idiosyncratic allocation of funds and chance for abuse.

Fifty percent of the states require academic affiliation for a grant. The type of research that can be funded is diverse, although applied research, targeted to specific needs, is the most prevalent. ("Applied research" is appropriate if the goal is to find a means whereby a recognized and specific need may be met.)

Another relevant question in the matrix of state science and technology programs is "Who benefits?" At a minimum, that question involves both eligibility requirements and patent rights.

For forty percent of the competitive grants programs sampled by the National Governors Association, patent rights are negotiable. Of the 28 separate states represented in that study, only five give patent rights in at least one of their programs to the university or college involved.

Two notable aspects of eligibility are location and size of business. If Small Business Innovation Research businesses are factored out, there are seven states that require the grantees to be located entirely within the state (California, Maine, Maryland, New York, Oklahoma, Oregon, and Texas).

Almost all grant programs require a match, unless the grant is only open to university applicants. A one-to-one match ratio is most common. However, two-thirds of the programs that require a match allow services in kind and/or federal funds to fulfill the match requirement, so that most often it does not represent an investment from the match partner.

2. WISCONSIN

Although education institutions in Wisconsin as well as State government have much to be proud of in their efforts to transfer university knowledge to the economy, more attention should be paid by the State to continuing the existing links between university and industry. The main focus of State grants programs is on initiating links. Largely without State help, university faculty have already forged working links, and there seems to be little acknowledgment within State government that these endeavors exist. A State R & D grant structure to support proven efforts should be considered.

The Wisconsin Technology Development Fund does include Applied Research Grants. Distribution regulations for those funds are currently being formulated. But the thrust seems aimed at formation of new alliances between university and industry, and the grant fund makes provision for first-year feasibility studies. Such funding is useful for major university initiatives into new areas, or new forms of organization, like the Biotechnology Institute. Likewise the Technology Development Fund is aimed at encouraging business to start links with Wisconsin's universities.

However we believe that those states that play through peaks of strength and success, i.e., those that have incorporated past performance rather than promises via proposals into selection criteria, have done best. In addition, there is some evidence that faculty members who have already been funded by industry are more likely (by a factor of four in one

study on biotechnology)[12] to seek research topics that may have eventual commercial application.

Close linking between faculty and industry during the early configuring of a research project seems to be most productive of eventual commercialization. A recommendation for a grant structure that does this was made by an Advisory Committee on Industrial Innovation of the U.S. Commerce Department, which in 1978-9 examined federal policies for industrial innovation. Adapted for Wisconsin, that proposal would include the following:

RECOMMENDATION

The State would establish a grant program to encourage faculty members from all Wisconsin education institutions to work with industry. The program would simply match at rates of "x" to 1 every dollar (no in-kind or gifts) provided by industry for research at any of the institutions. The matching ratio could be increased for Wisconsin-based companies. The matching funds would go to the group or individual, but not necessarily to add to the particular work which received industry support. In other words, it could supplement the corporate project effort in whole or in part or it could be "seed money" for often high-risk research of new, advanced generic technology. The State would have the assurance that this work would be done by faculty that have a proven interest in working with industry. The funds might also be used for start-up costs for faculty who wish to pursue research in a new generic technology. The value of "x" in the ratio above provides an ideal, simple, directly-connected term for a policy-making legislative body (see below).

ADVANTAGES

The advantages of this matching grant program are:

1. Absolute minimum administrative cost.

2. Conservation of valuable time of faculty and industry. Requirements for application like those of the National Science Foundation, which run into dozens of pages, if not hundreds, mean that the research community's time is burdened by grant-writing and the massive paperwork necessary when they do obtain a grant. The research community is, reasonably enough, up in arms about this waste. More often than not the time spent in grant-writing is non-productive; the percentage of successful applications to the National Science Foundation's 84 competitive grant programs, for example, is only 30 percent. For the larger grants it has varied recently from 5 to as low as 1 percent. The administrative cost of the grant-giving institution has also risen, leading one long-time reviewer to comment, "It has gotten to the point that it's almost not worth getting together a panel (to review new grant applications) because it's so expensive, you could almost fund another grant with that money. And if you're only going to funding seven or eight grants, adding a ninth makes a difference."[13] Saving the scarce time of productive faculty should be required in any new program.

3. The program budget is very easy to fine-tune. The legislature can easily change the grant ratio. It can put smaller or greater incentives for Wisconsin industries, for collaboration between institutions, or for any variable necessary for equitable allocation of resources. For example, for Wisconsin-based companies the ratio could be increased.

4. The review system is the most pertinent and most honest one available to innovation research. The typical peer review consists of a few anonymous comments and checking a

box after reading a 20-50 page essay. The proposed review system here is more useful; industry not only visits the faculty and works with the operation, but also has backed their judgment with tens of thousands of dollars. This is the best performance criterion available to state funding. Based on proven mutual interest and performance, not on expertise in proposal-writing, this is the most informed way to try to keep innovation coming. It is not a "matching" grant in the usual sense since it is not for the funded project but for use "in the general area of technical interest represented by the industrially-funded project."[14] It is closest to real industrial needs and problems while still taking care to provide for vision.

The established pattern is for universities to match grants (in 1-5 percent amounts) from the federal government. And yet, government grants represent priorities designed to serve national needs, not local or regional needs. Even money for Small Business Innovation Research is massively dependent upon military allocation; the Defense Department accounts for 55 percent of Small Business Innovation Research funding. As one faculty member put it, "Industrial grants are more likely to lead to a product or to improved products or processes than are government grants, and yet the state is willing to match the latter and not the former." The above matching-grant proposal would remedy this situation. Reorienting facilities which have looked to Washington for forty years will take changes in both federal policy and state initiatives.

Given the current situation, faculty have less incentive to go after industry than to seek federal government grants. Companies typically talk about supporting one student for $16,000 per year, whereas by writing one proposal every three years a faculty member may get a quarter of a million dollars from the government and be able to support five or six students. Company support at $100,000 per year for three years is extremely rare. A few European and Japanese companies in other states with matching programs are putting in $50,000-$100,000 per year.

A faculty member would have to do a great deal of hustling to get several companies supporting research in small amounts so that the total would be attractive, and, importantly, even then the support might not be ongoing. Research is not something that can be turned on and off from one year to the next and still flourish.

B. CENTERS

In addition to competitive grants, another major thrust of federal and state efforts in the area of science and technology programs in the last 10 years has been technology centers. In Wisconsin universities there is an impressive array of such centers, institutes, and programs. They have been developed, largely without state aid, by innovative faculty in a variety of research areas and often have consortia of companies supporting them. In the College of Engineering at Madison, the following units are a part of our study and give some idea of the endeavor at the campus (this is not an all-inclusive list of the College's centers):

Applied Superconductivity Center
Energy Research Center
Engine Research Center
Engineering Research Center for Plasma-Aided Manufacturing
Manufacturing Systems Engineering Program
Materials Science Center
Nuclear Safety Research Center
Water Chemistry Program
Solar Energy Laboratory

Thin-Film Deposition and Applications Center
Trace Research and Development Center
Wisconsin Center for Applied Microelectronics
Wisconsin Center for Space Automation and Robotics
Wisconsin Hazardous Waste Management Center
Wisconsin Power Electronics Research Center (WisPERC)
Wisconsin Structures and Materials Testing Laboratory
Bioprocess and Metabolic Engineering Consortium
Cast Metals Program
Consortium for Redrawn Inviscid Melt Spinning and Related Fiber Technology
Ductile Iron Consortium
Wisconsin Information Sciences and Communications Consortium
Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC)

At UW-Milwaukee, research centers of excellence are established in the Center for Great Lakes Studies, the Laboratory for Surface Studies, the Urban Research Center, and the Center for Twentieth Century Studies. UW-Milwaukee's faculty affiliated with these centers bring in between thirty and fifty percent of the campus's total external funding.

Almost all of the research programs on which centers are based have obtained industrial funding and many have federal monies. At this stage there are three needs that will have to be addressed if any expansion is desired and, perhaps, if the current efforts are to be sustained.

1. Administrative personnel. In order to set up the many centers, administrative time has been and will continue to be needed and expanded. Faculty and deans have been able to do this, but, if continued efforts are desired, modest additional resources will be needed. Otherwise, the instructional budget and instructional time will be necessarily raided. The legislature cannot ask for more "outreach" without endangering both teaching and research time, a threat that some feel is already a reality.

Necessary personnel may be at the level of administrative assistants, for example in the Dairy Research Institute, or of the level of an administrator with substantial technical expertise to oversee efforts throughout a college, for example in the College of Engineering at Madison. There should be a study of the administrative needs of centers and institutes, wherever the links with industry are, and an appropriate response. If the teaching and research mandate of the faculty is increasingly turned to administration and fundraising, the pursuit of knowledge as well as any possible transfer to industry will suffer, and probably already is.

2. Technicians. The laboratories around which centers or institutes revolve require technicians to maintain equipment and safety for both teaching and research. This is both an instructional and genuine research-science need, especially relevant to industrial research. In UW-Milwaukee, for example, equipment is being left idle because of maintenance problems and the need for supervision and safety of students. Instruction as well as outreach initiatives by faculty will be handicapped without a few additional technicians.

3. Facilities. It is outside the scope of this report to study the physical plant of the universities involved. However, it was clear that the faculty who have a substantial history of knowledge-transfer efforts to industry and who wish to build further on relations with industry--in short, the go-getters--are plagued by lack of space and poor facilities. The *Capital Times* explored this issue in several articles in the winter of 1989, and our

observations are in accord with that report about decaying facilities.[15] Not being able to provide space expeditiously will be a fundamental flaw that faculty will not be able to overcome, and, since responses to industry interest will hinge on this, particularly for major consortium work, the kingdom may be lost for lack of a horse. Universities are notorious for unwillingness to re-allocate space from old high-priority functions to new areas. In a zero-sum economy, with priorities changed to applied science, this question needs to be studied independently.

C. LONG ODDS: INCUBATORS

Many commentators agree that the best incubator for business is a city, that is, a place where financial and institutional resources are readily available, as well as a labor force. Further, although universities can be helpful in providing a suitable quality labor force, universities are not a major source of new firms. It is the firms spun-off from old firms that seem to be the viable source of growth. Thus, unless all the infrastructure is available, it is doubtful that incubators and research parks will greatly aid economic development. This seems especially true of high technology industry, and it will be very difficult for states that do not have a strong high technology base to establish one. For example, substantial efforts have been put into high technology development around Austin, Dayton, Tucson, and Raleigh-Durham, but, thus far, the entrepreneurial spin-off activity of Boston's Route 128 and Stanford Industrial Park have not followed.[16]

The evidence being amassed after a decade of study, especially on high technology innovation, indicates that small businesses fail at a large rate and do not tend to grow. Rather, it is new, small firms that emerge from established, large business that provide viable economic development. It is chancy at best for government to put resources into research parks and incubators in the hope of economic development. The State of Wisconsin has put minimal resources into these two types of efforts, which is probably all to the good, as the following research findings indicate.

HELPING SMALL BUSINESS

State incubator programs are largely a child of the eighties, and, going into the new decade, half of the states have developed incubator facilities. Self-studies by those who operate incubators for small business obviously come out positively. The data here are always self-serving. Outside commentators cast a doubtful eye on the reported success of incubators. One recent study of Pennsylvania incubators is of special interest for two reasons. First, the study included a control group. And, second, Pennsylvania has one of the earliest and biggest of the state incubator programs. The researchers collected data on the Pennsylvania incubators and their tenant firms and compared a control group of non-incubator firms to Pennsylvania incubator tenants. They found that few incubators break even without outside financial support, and the hoped-for revenues to break even or make a profit have not materialized. And, about half of the incubators currently charge market rates or are full so that an increase in tenancy or rents is not possible.

When non-incubator firms were compared to incubator tenants, they found that Pennsylvania incubator tenants performed on par with non-incubator firms on some measures but less well on others, and they infer from these findings that "incubators do not add value to tenants above and beyond what non-incubator firms can get from the marketplace outside of incubators." To the question of whether incubators make a difference they answer that, although tenants report valuing the services highly, one-half of the tenants never used any given type of business assistance and one-third never used the

office services. In short, incubators do not make a difference when tenants are compared to statewide, market place firms.[17]

Though incubator studies done by outside consultants using control groups are rare, other comparisons can be made. For example, a study of the National Science Foundation's Innovation Centers Program that explored data on what works and what does not in helping small business indicates that the effective assistance to start-up business was marketing and business assistance. Technical assistance and logistical support had no effect.[18]

D. RESEARCH PARKS AS STATE INITIATIVES FOR ECONOMIC DEVELOPMENT

There are currently an estimated 130 university-related research parks in the U.S., most of them built in the 1980s. But, as effective instruments of technology development in concert with university expertise, there is little evidence for the success of research parks. Because many have been established recently, some of the data is preliminary and more successes may be seen eventually. But, in general, research parks have a high rate of failure. One study of 27 university research parks found that 16 failed, 6 succeeded and 5 fell somewhere in between.[19] These are not very good odds for investment return. As one student of technology-based economic development puts it: "University-related research parks are regularly cited as examples of effective technology development policies, but in fact such parks have a poor record of success...In sum, the US experience with research parks, with only a few exceptions, has not been a favorable one. The few successes have been located in large urban areas; in general, research parks have not generated a significant number of new firms."[20] Predominantly because of the NASA and Department of Defense money that poured into Route 128 near Boston and Silicon Valley in California, those two areas have flourished. Those developments took place in a different era, and had virtually nothing to do with university initiatives.

Even if that history could be repeated, there is no evidence that spin-off companies associated with research parks have occurred in numbers greater than the market would have provided elsewhere. In general, research parks have not led to new firms.[21] Research parks have also not managed great success integrating university expertise into the endeavor. Perhaps this is because, as we mention elsewhere, university-industry cooperation has been largely formed though faculty-industry linkages. Research parks are largely devised by administrators, and it is a new endeavor to most of them. A General Accounting Office report in the early eighties posited that a successful research park needs to have an "ongoing relationship with industry be an integral part of the university's mission, and the strengths of the university and the interests of park tenants must be well-matched."[22] Research parks tend simply to take whatever tenants they can get.

The Research Triangle Park in North Carolina, which resulted from unusual long-term planning by the state and consistent commitment from government and banking, is also often cited as a success. However, almost no spin-offs have resulted since its beginning, which was thirty years ago. Its main success has been to bring in the research facilities of large corporations.[23] Other attempts at attracting corporations to research parks, which look suspiciously like a 1980's form of smoke stack chasing, illustrate that even this is not easy. "When Washington State University and the city of Pullman created a research park in 1982, university and local officials expected a Boeing or Hewlett-Packard to move in and convert the agriculture-dependent region into a high-technology corridor teeming with

new jobs....The officials are still waiting."[24] The truth is that no one yet knows what elements are necessary to insure knowledge transfer from university to business to commercializable product. Most lists of what will make research parks work are merely compilations of everything that has been tried with no evidence that the components are causal.[25] It is obvious that it is difficult to give a shape to a research park that will result in even modest, productive linkage between business and academia and become more than an attractive section of land with pleasant ambience and good public relations. "These are not the answer...This is not a technological free lunch," as James D. Morrison, of the University of New Hampshire and an avid follower of research park trends, recently pointed out.[26]

The Research Park that is underway in Madison has two primary goals:

1. To provide real estate for industry that allows for interaction with the university.
2. To create an endowment for research later on.

Secondarily, it is thought that the Research Park may serve to bring in capital for start-up firms originating in the university.

The physical facilities that will house the Research Park are well underway. This, of course, is the easiest step in the process. It is far too early to even begin to evaluate the prospects for financial success upon which number two, the creation of an endowment, is dependent. Although data seem to indicate that we are overbuilding 26 research parks, regional economic conditions make each case different.[27]

V. ASSUMPTIONS UNDERLYING POLICY FOR INDUSTRY-UNIVERSITY COOPERATION: CONFUSIONS AND QUESTIONS

MAJOR CONFUSION

One error persistently made in discussions of university-industry relations is to confuse assisting industry with the creation of commercializable products and processes, that is with transferring technology. Although patents may signal successful research, only in very rare cases--though there are examples--is a technology developed within the university research laboratories. And, even when a new technology grows out of the confines of a university lab, it is not that innovation per se that can insure a successful business venture. When a technology does emerge from a research lab, data indicate that the market success or failure of a solution is determined by whether or not an understanding of the future users is present at a very early stage of development. This is why targeted research, that is research focused on a specific problem, pulled by the market, and usually short-term, is effective whereas basic research is usually not a profitable investment in the short-term. In one case studied for this report, a genuine technology transfer from Medical College of Wisconsin research was involved. However, even with a close match between use and development, market influences (for example, cost and competition) may scuttle an attempted-innovation.[28]

For the most part, the product of the university is knowledge, not technology, and, properly speaking, it is knowledge transfer that should be examined for problems and usefulness. When used in regard to universities, there are several common and unfortunate outcomes of this misnomer "technology transfer." First, business and industry are given unrealistic expectations of what universities can do for them. The result can be disillusionment on the part of industry, going from the notion that research can do everything to the idea that it is useless. Although short-term, targeted research can be useful to industry on a contract or consultant basis, universities are not in the business of product development. There is a quandary for university, that is, whether the aim of research should be applied or basic research. In Wisconsin there is a mix of both, and the probable, immediate usefulness of each should not be confused.

FACULTY AS ENTREPRENEURS?

On the one hand it is obvious that generally faculty are not entrepreneurs. They have self-selected into the academic profession because they do not want to be business entrepreneurs. But--and here lies the confusion--this does not mean that they are not problem-solvers or that they have nothing to contribute to the economy. Quite the contrary obtains for engineering faculty, and often science faculty also. Anecdotal accounts of "ivory tower" faculty are not generally true of engineering faculty. Both personality studies and a look at what engineering faculty teach and do, indicate that they are problem-solvers par excellence. This is what they have self-selected to do as a profession. In sum, engineering research and teaching have always been a part of the economy. Our case studies indicate that such links are a continuing part of the university culture and are a major real, and potentially greater, resource to the state.

However, the culture of academic engineering is one that has traditionally focused on the question of "how to make it work." Only secondarily, and not fundamentally, does it promote the question of "how to make it profitable." It is true that in the sixties and seventies, the tendency to ask "is it fundable by federal agencies?" took over and that these federal agencies tended to favor more analytical and often esoteric research, of not much value to civilian product-engineering. We recommend strongly against continuing the rhetoric of the eighties of encouraging faculty to become entrepreneurs. Instead the rallying cry of the nineties should be one of service to society, national, state, and local. A part of this may be accomplished by faculty teaming up with large, medium, and small industry and entrepreneurs. The earlier rhetoric had these dangers:

First, asking faculty to change to the mindset of entrepreneurship will encourage the loss of personnel. University engineering departments are already struggling for personnel, and will have an increasing problem by the year 2000 when 50% of all current engineering faculty will retire. The "pipeline problem" is a hot topic of discussion these days to all concerned, the federal government, universities, and associations of professional engineers. Engineering research and teaching capacity has been severely limited in the 1980s. The problems of inadequate space and too many students per faculty has meant that at least two dozen engineering schools in the country, some of them quite prestigious, have had accreditation problems. Unless industry wants to assume the burden, someone must be left in the university to train the next generation of engineers. Adequate production of engineering graduates is important to the economy in the long run; its value is a sure thing. As the president of Carnegie-Mellon University put it: "The problem of CMU is the very success of consortia...you attract the venture capitalists who go after the scarcest resource a university has--its intellectual capital of people. There is a lot of temptation to create spin-offs. The tension this creates in the institution is enormous."[29] Trying to make entrepreneurs of faculty may do more harm than good.

Second, asking faculty to keep an eye on economic profits is, indeed, to radically change the academic culture. The benefits of that change are dubious and the costs enormous. Teaching students how to make money before one teaches them how to think analytically, to spot anomalies, to value precise thinking and language, to understand the difference between evidence and opinion would constitute an intolerable change. Linking the financial support that outfits laboratories and supports students to the production of commercializable products will not necessarily produce quality engineers or be in the best interests of our economy.

Third, the trend for the universities to promote patenting, licensing, and spin-off business shows how the interests of academic science and engineering and business can collide, to the detriment of both. Commercialization as a university goal has already created obvious problems; academic medicine and the recent flaps over high-tech superconductors and cold fusion are examples. As we have shown above there is no evidence that, except for a handful of research universities, anyone can really hope to produce a significant income stream.

For example, the case in the mid-1980s of Harvard medical researchers who formed and held stock in a company while at the same time doing clinical trials of the ophthalmic ointment that was the company's main product is illustrative of the dangers that lie down that path. Although the behaviors of those involved created a clear conflict of interest, that is not the worst outcome. With an eye to profits, the processes of scientific inquiry were altered. It is scientific procedures, as opposed to those predicated on profitability, that have made the university product--knowledge--distinct and valued by our society. In the end, the investors were ill-served by being given poor information about the usefulness of the ointment and the prospects of the company. Negative publicity and new, valid and negative studies have left the value of the company's stock languishing near rock bottom.

Along with conflict of interest and resultant shoddy science, the eye to commercialization has also already had a major damaging effect on the free flow of information among those who are doing engineering and scientific research. The opportunity to repeat experiments, and thus to falsify them, is crucial to scientific progress. And, it is predicated on free exchange of information. The concern of the University of Utah with the profit potential of cold fusion led to highly-visible problems. Others have also documented similar examples and trends.[30] Research universities will cease to be of service to industry, or at least only to the few, if the healthy and open competition, based upon relatively free exchange of information among researchers, devolves into competition for patents and profits.

OUTDATED MODEL

The cry to make entrepreneurs of engineering faculty is based on a predilection for an old and honored paradigm, the belief in the individual going out and making America wealthy. The faculty, who are tenured, are neither willing nor able to do this. There is a new paradigm, however, that makes more sense in the current situation. The new paradigm, represented by the report of the Massachusetts Institute of Technology's (MIT) Commission on Industrial Productivity, *Made in America*,[31] and Don E. Kash's book *Perpetual Innovation: the new world of competition*,[32] is of team work and cooperation. Included in this paradigm is cooperation between assemblers and subcontractors, corporations and government managers and workers, academia and industry, and within academic disciplines. The universities will have to change greatly to become part of this new paradigm. For example, multidisciplinary or interdisciplinary teams will be a keynote in both education and research and will require alteration in curriculum and in organization.

There have been fledgling attempts in both these directions in education. The rigid commitment to disciplinary structures in a world which has no strictly disciplinary problems or solutions does not bode well for relevance to the states' needs. For over thirty years, gentle federal nudging, accompanied by very substantial incentives (i.e., $30 million per year for 25 years) to foster interdisciplinarity in materials research have had virtually no impact. Encouraging or requiring universities to institutionalize interdisciplinary structures may be the state's most important policy input into university life.

Although MIT is touted as having an exemplary record of relations with industry, when MIT had a look at itself, they found themselves lacking. The MIT Commission saw a great need and "challenge in advancing and using engineering science to tackle pressing, real problems...." They go on to recommend revising subjects to include team projects, practical problems, and exposure to international cultures.[33] They suggest that faculty members should supervise project teams that explore real-world problems, such as the design of a computer system for a nursing home, robots for cleaning Boston harbor, a solar home, or a manager's workstation. These recommendations for improvement, which the authors intend as national recommendations, sound very like what has been done at MSOE for years and is now being done to a lesser but growing extent at Marquette and UW-Milwaukee. As the MIT Commission notes, there is reason to feel ill-at-ease with the way engineering is taught in many institutions, but the problem is one of switching from discipline-based to cooperative, team-based learning.

Thus, a major change in university culture is in order in regard to cooperation between fields, which will also help strengthen the traditional links with industry. Calling for entrepreneurship on the part of the faculty is the wrong answer to a non-existent problem.

WISCONSIN LOOKS GOOD

In comparison to other states, Wisconsin looks very solid and effective in its transfer of knowledge from its universities to industry. This includes relevant research, centers, consortia, and utilization of patents.

However, it should be highlighted that, aside from the obvious statement that each institution should build on its own strengths, there is no Wisconsin state policy concerning research directions or transfer of research knowledge to industry. Decisions about what scientific and technical information to go after and to use to derive new goods, services, and processes are largely ad hoc endeavors in Wisconsin.

If a more focused policy for university-industry cooperation is desirable--and it may not be--the concerned parties should have a look at what holds maximum potential for economic and social good in Wisconsin. We have recommended a very simple State initiative as the core of a new Wisconsin policy to encourage enhanced interaction of its university faculty with industry, and especially Wisconsin industry. This is a simple system of matching grants through which actual dollars supplied by industry are matched by the State. A further part of a true policy process will be to decide what Wisconsin is, what it wants to be, and how to get there. As has often been pointed out, expenditure of public funds for direct support of research and development must be made within the context of the direction of innovation as well.[34]

VI. POLITICAL SETTING IN WISCONSIN FOR UNIVERSITY-INDUSTRY COOPERATION

THE LEGISLATURE VERSUS THE UNIVERSITY

There is a tension "in the air" over possible conflicts between the university and the legislature concerning both the research and the outreach missions of the university, which more and more includes cooperation with industry. Some see this as an ambivalence on the part of the legislature as to whether it wants research and outreach at all or would instead like to put most resources into teaching. Some feel that the legislature, as well as newspapers, have an underlying presumption that consulting and transfer of research knowledge to industry is wrong. The fact that public disclosure of income is required for faculty who make $5,000 or more in consulting seems to them to be viewed in such a way that faculty will be discouraged from working with business and industry.

However, the many public relations/outreach activities of the colleges of engineering included in this study testify to the fact that any such difficulties have no major effect on the willingness of at least some of the faculty to cooperate with industry. Certainly the consortia leaders sampled in this study were not deterred from their efforts. Also, the long-term commitment to the University-Industry Research office and the Office of Industrial Research and Technology Transfer indicate some willingness on the part of the legislature to support transfer of university research knowledge.

The problem stems perhaps from the resistance of the university to accepting the legitimacy of public debate over public resources. The concern about the value of research and development is certain to increase steeply as the U.S. market share in high technology continues its inevitable downward trend. There should always be a tension between the university and the state legislators, that is, the legislators should always be asking informed questions about whether the people of Wisconsin are getting their money's worth. This concern is imbedded in questions by legislators about teaching loads. In addition, the areas of equitable distribution and access need to be perennially addressed. Legislators are the guardians of public funds, and being concerned about the allocation of the massive university budget is their proper role. University personnel need to keep this in mind and not let legitimate inquiries have a chilling effect on their own work or any outreach to industry.

These initiatives are part of increased productivity of the faculty and need to be formally acknowledged as such by the legislature and the university administration (unless a decision against this form of outreach were made by the legislature). We looked at one example outside of engineering, the Dairy Research Center, but there are several other significant areas of business-university cooperation where the focus is managerial, for example the programs of the UW-Madison Business School and the Small Business Development Center. Many of the legislators are conversant with the consequences of long-term funding for a program of education, research and technology transfer provided through agricultural extension, but they are less informed about recent initiatives in outreach to industry. They must become so if they are to contribute to the needed policy process and direct funds wisely and efficiently.

Especially during the last ten years U.S. university outreach to industry has grown in acceptance and visibility, although in percentage of total R & D support it remains quite minor (6 percent) in most places. If the legislature wants to increase university outreach to industry then negotiations over additional resources are necessary. Space will be a problem that faculty cannot solve on their own. The same will obtain for some

administrative support and start-up costs for new faculty. A clear articulation of conflict-of-interest rules and the intellectual property issue, particularly in relation to spin-off business from university research, will no doubt be on a future agenda as will patenting for the university system as a whole. With these agendas upcoming, it will be necessary for legislators to keep abreast of the faculty-initiated outreach to industry.

ENDNOTES

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ABOUT THE INSTITUTE

The Wisconsin Policy Research Institute is a not-for-profit institute established to study public policy issues affecting the state of Wisconsin.

Under the new federalism, government policy increasingly is made at the state and local level. These public policy decisions affect the lives of every citizen in the state of Wisconsin. Our goal is to provide nonpartisan research on key issues that affect citizens living in Wisconsin so that their elected representatives are able to make informed decisions to improve the quality of life and future of the State.

Our major priority is to improve the accountability of Wisconsin's government. State and local government must be responsive to the citizens of Wisconsin in terms of the programs they devise and the tax money they spend. Accountability should be made available in every major area to which Wisconsin devotes the public's funds.

The agenda for the Institute's activities will direct attention and resources to study the following issues: education; welfare and social services; criminal justice; taxes and spending; and economic development.

We believe that the views of the citizens of Wisconsin should guide the decisions of government officials. To help accomplish this, we will conduct semi-annual public opinion polls that are structured to enable the citizens of Wisconsin to inform government officials about how they view major statewide issues. These polls will be disseminated through the media and be made available to the general public and to the legislative and executive branches of State government. It is essential that elected officials remember that all the programs established and all the money spent comes from the citizens of the State of Wisconsin and is made available through their taxes. Public policy should reflect the real needs and concerns of all the citizens of Wisconsin and not those of specific special interest groups.