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J. A. BONNET, JR.

AND

J. T. PYTLINSKI.



CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO - U.S. DEPARTMENT OF ENERGY

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J.A. Bonnet, Jr. and J.T. Pytlinski
Center for Energy and Environment Research
University of Puerto Rico
San Juan, Puerto Rico 00936

Introduction

The growing economic importance of technological innovation has created a greater need and new opportunity for cooperation between industry and university. The general aim of cooperative research is to develop a basis for orderly flow of scientific and technical information between university and industry.

University researchers and administrators are aggressively looking for new ways to fund university research. Among options being actively considered are programs to commercialize university research and to foster university/-industry cooperative research. This latter type of collaboration fosters and contributes to industrial innovation and regional economic development by:

1. Reorienting university research toward the needs and interests of industry.
2. Increasing the speed with which research results become available to industry.
3. Allowing wider and more efficient use of university facilities, equipment and personnel.
4. Improving the quality of training for scientists and engineers.
5. Attracting high technology firms and encouraging the creation of new businesses.
6. Improving the productivity and competitiveness of businesses already in the region.

These activities cover a spectrum of interactions, from joint research endeavors to cooperative participation of university and industry scientists, from contract research to the establishment of research consortia.

Interactions can involve not only financial support of research, but also donations, transfers, exchanges, and sharing of people, equipment, and information. A university/industry interaction can be the basis for establishing a center or institute oriented toward industrial research interests or at least a definable technical mission.

Most university/industry centers have a combination of state, federal, industrial and academic support. For the most part, such centers are addressing areas of interdisciplinary research. The most critical factors in developing such centers are university support, industry interest in providing long term financial assistance, faculty interest in cooperative research with industry, and a dynamic leader with a sense of direction.

The relationship between university and industry cooperation depends on local conditions and needs. Because of this, universities are reviewing their policies regarding research, patents, licensing, publication, and outside activities of faculty.

The Center for Energy and Environment Research, a specialized unit of University of Puerto Rico System, has been acting as a catalyst for promoting university/industry research cooperation on the island aimed at setting up a university/industry research program within the University.

GENERAL PHILOSOPHY OF UNIVERSITY/INDUSTRY COOPERATIVE RESEARCH

Increase in internally funded basic research in industry is usually concurrent with increase in industrial support of university research. A favorable climate exists for increased university/industry research interactions. It can be summarized as follows:

- a. Disenchantment with restrictions in federal funding is causing universities and scientists to look toward broadening their funding base.
- b. Several scientific fields have reached maturity, and industry is in a position to recognize their potential for new business (biogenetics, microprocessing, high technology ceramics) and for increasing industrial productivity.
- c. Industry is expressing with some degree of urgency an interest in, and need for, specific types of technical personnel.
- d. University scientists are beginning to look to some industrial laboratories as a way to gain access to the most recent research equipment and technical advances.

These forces have contributed toward interest in university/industry research interactions.

The functions and objectives of the academic and industrial sectors govern their institutional structures, their organization and management of research. Universities tend to be more pluralistic; their faculties form the framework of their organizational structures. Industry is structured for goal-oriented outcomes. Therefore, it generally follows a more hierarchical, structural plan. The respective objectives and functions of university and industry also affect their approach to cooperative interactions.

Academic research institutions exist primarily to educate students and to discover and extend knowledge. The founding charter, motto or statement of purpose of a university frequently explains its present orientation. Freedom of communication and publication is essential.

Attitudes towards research in universities are governed by their educational and research missions. Most universities start with the notion

that research is an integral part of education and training. Both research and training in their view are essential in the pursuit of knowledge. Thus industry support for research is inextricably related in many ways to the educational mission of universities. Universities, both public and private, are also committed to public service and the dissemination of knowledge.

In general, despite different university orientations, university research has three goals which are rarely in conflict with each other. They are:

1. To train students in research techniques.
2. To provide state-of-the-art information in fundamental and applied research, and
3. To serve as a source of financial support.

Industry, however, exists to provide the optimum return on investment consistent with stable growth; it does so by producing a product, process, or rendering a useful service. A factor in this process is the development of proprietary knowledge, which often necessitates that patent protection be established. Industry's approach to research and development is ultimately governed by the view that research is a long-term investment whose function is to provide eventual payoff.

There are more than 2,000 colleges and universities, and 14 million businesses, not counting the subdivisions of corporations. Each has its own structure and organization, and this complicates discovering areas of mutual interest.

Yet, an obvious overlapping interest of the two institutions is the production of well-trained and educated students. Furthermore, industries are continually seeking new ideas, new knowledge, and fundamental concepts, precisely the goals of research at universities.

The changing role of science and technology in society will most likely affect university research subjects and the proportion of basic to applied research conducted at universities and sources of funding for university research. This may have future implications for university structure. There is a continuous spectrum from basic to applied research, what is one organization's applied research can be another's basic research. Basic research at universities and colleges accounts for about 50% of all basic research in the U.S. Industry conducts about one-third as much as the universities, and government laboratories about 25% less than industry.

Most universities (80%) receive less than 10% of total university R&D expenditures from industry. It is obvious that some industrial sectors may have underutilized the university as a resource, since for the current level of \$6 billion annually in total R&D conducted at universities only \$300 million comes from industry. The bulk of U.S. research is conducted within 20 major research universities and 20 corporations.

About one third of industrial R&D is funded by the federal government, the remainder by industry itself. Industrially funded R&D, however, is on an established upward trend, and the breadth and scope of research currently underway in U.S. laboratories suggest that there will be a renaissance in technological vigor during the 1980s.

The importance of top level administrators in setting the tone for university/industry research cooperation and encouraging such interaction is essential. In several institutions, both public and private, new administrators have recently been hired with the specific directive of fostering university/industry research ties. Other practices of fostering personal interactions, such as participation on advisory boards, seminars, speaker

programs, publication exchange and adjunct professorships, could lead to greater cooperation between university and industry.

Such programs require a consistent level and continuity of funding. Cooperative research interactions require some degree of cooperative technical planning. The major objective of such support is to strengthen company and university research ties. Institutional agreements are frequent instruments for formalizing university/industry research cooperation. In addition to technical matters, non-technical matters must also be considered by such agreements. Most frequently, these aspects concern allocation of resources and disposition of the outcomes of joint research efforts. These agreements must take into account university procedures and policies and industry objectives and proprietary concerns. Such agreements form the basis and foundation for subsequent university/industry research cooperation.

A number of universities have held special conferences, many of them sponsored by industry, to attract more formal industrial support in a specific area. In many instances the newly created industrial advisory councils typically associated with engineering and agricultural schools and institutes of technology are useful in providing information about current industrial concerns, and allowing industrial input on research directions and curriculum development. The councils can also help in soliciting funds from legislatures and/or getting equipment for the university. Also, large research companies, especially in electronics, often have scientific advisory boards composed of university scientists. These boards help ensure that industry does not lose sight of new technical directions, and that they keep up standards of excellence in their research programs.

The willingness and the ability of a university to participate in large research programs could be an important factor for future university/industry cooperation. Sometimes university alumni, having become corporate executives, suggest discussing joint programs. Sometimes the government brings universities and industry together to conduct research as part of a national effort in a particular area. A critical element in the development of many of these programs is government seed money. Most of the large, industrially funded programs in the beginning were funded, to some extent, by the government.

Federal support can be helpful, and has been critical in many instances. However, the partners themselves have been the key elements in successful program development. In the traditional university/industry coupling mode, the government, in the role of matchmaker, brings the two parties together and provides the initial funds. Government funding for cooperative university/industry research is provided by many government agencies, including the Department of Defense (DOD), the Department of Commerce (DOC), the National Science Foundation (NSF), the Department of Energy (DOE), and others.

INCENTIVES FOR UNIVERSITY/INDUSTRY PARTNERSHIP

Industry has many reasons to be interested in establishing research interactions with universities. They could be listed as follows:

1. To obtain access to manpower (students and professors).
2. To obtain a window on science and technology.
3. To solve a problem or get specific information unavailable elsewhere.
4. To obtain prestige or enhance the company's image.
5. To make use of an economical resource.

6. To obtain general support of technical excellence.
7. To be good local citizens and/or foster good community relations.
8. To gain access to university facilities.

Access to high quality manpower is the prime motivation underlying industry's desire to establish cooperative research activities with universities. Industry also looks to the university to solve very specific scientific problems in which the university has specific expertise. Industry rarely looks to the university for technological innovations that directly result in new products or processes.

Closer relations might lead to expanded research by universities in areas of basic science and engineering that could be built upon by industry for future growth. Greater rapport between industrial researchers and faculty could strengthen support for graduate students and, presumably, increase industry funding for university research. Cooperative programs might provide leverage for further grants, and thus expand the level of basic research generally.

Most companies recognize the role of the university in basic research and in training students. Their interest is in students and access to new ideas rather than to a specific product, process or service. Frequently, companies hire students whom they have sponsored in a university/industry cooperative research program. Faculty may also be hired after participation in these programs.

Companies are particularly interested in access to graduate students as potential employees. It is not at all unusual for a graduate student working on an industry sponsored research project to work for the sponsor upon graduation. Hiring such graduates offers great advantage to industry, since costs of recruiting, and initial on-the-job learning are reduced, if not

eliminated. As university/industry cooperative programs increase in number, there is a belief that the number of Ph.D.s oriented to an industrial career will increase, or at least new Ph.D.s will be better prepared to meet industrial needs.

Industry support of graduate research assistants is perceived as cost effective, not only for its own sake, but also for its recruiting potential. Thus, science-based companies that are expanding or have high turnover rates of technical personnel are more likely to support university research vigorously by joint university/industry research programs. Another reason for industry's support of a university is to increase the representation of minority graduates in science and engineering.

Industrial funding provides the kind of flexibility for research and development critical to graduate training at the University. Another element of company motivation is prestige; support of "pro bono publico" research is good public relations. It enhances the company image. Also, participation in these programs boosts the morale of scientists in industry who welcome the chance for joint authorship in scientific publications.

A further prerequisite to such arrangements seems to be the desire of a company to extend their research capabilities into new fields. Low technology industries may also come to the university for solutions to technical problems.

The reasons universities choose to interact with industry can be summarized as follows:

1. Industry provides a new source of money. This helps diversify the university's funding base.
2. Industrial money involves less red tape than government money, and the reporting requirements are not as time-consuming.

3. Industrially sponsored research provides student exposure to practical research problems.
4. Industrially sponsored research provides a chance to work on an intellectually challenging research program which may be of immediate importance to society.
5. Government funds are available for research, based upon a joint effort between university and industry.
6. Cooperative research programs provide better training for the increasing number of graduates entering industry.

Economic need on the part of universities has been one recurrent pressure towards cooperative efforts with industry. However the strongest motivation in the university for interacting with industry, far above all the others, is the university's desire to obtain funds to strengthen basic research and graduate training, and to support the facilities that make that research possible.

CONSTRAINTS RELATED TO UNIVERSITY/INDUSTRY PARTNERSHIP

There is a consensus within university and industry communities that there are no critical barriers to joint university/industry research interactions, but that several constraints do exist. The existing areas of concern include patent and licensing conflicts, information dissemination restrictions (including pre-publication review requirements), handling of proprietary information, and outside activities of faculty. This may delay the signing of agreements and focus attention on non-technical issues of cooperation.

In setting up an university/industry research partnership the expectations of both parties must not be raised unrealistically beyond the normal research outcomes. There are instances of university/industry research

interaction that could be characterized as failures because university scientists promised more than they could deliver.

From the university point of view there seem to be three problems of special concern when initiating an industry research program:

1. Patents and licensing arrangements.
2. Pre-publication review requirements.
3. Proprietary information.

Such issues are being recognized and discussed by many universities around the country as expectations rise that a greater proportion of their research will be supported by industry.

The National Commission on Research, in its report on industry and the universities, suggested that the university might face certain constraints in these areas through participation in cooperative research relationships with industry. The Commission commented that universities may be influenced on research direction and become involved in more applied and development-oriented programs in this situation.

Industry discounts the first two as problems (patents and licensing arrangements; pre-publication review requirements) and feels that the third (proprietary information) can be resolved to mutual satisfaction. Industry's attitude is that such issues are negotiable.

In general some of the present difficulties in negotiating contracts may reflect the transitional state of many university policies pertaining to industrial support of research. Many universities are presently reviewing and changing many of these policies (e.g. whether or not they will grant a firm an exclusive license and for what period of time). Many patent policies at universities are under study or revision.

Questions such as the following are being addressed:

1. Is the patent policy up to date, or should it be revised?
2. Is the division of royalties between the university and inventor equitable, and sufficiently encouraging to the inventor?
3. Who should retain the rights to the patent? Should the university relinquish the right to the invention and under what circumstances?
4. At what stage and from what funds should the patent office overhead and other expenses be paid?
5. Under what office of the university should the patent administration lie, and which administrative officials in particular should have final say on a decision involving patents?
6. Does the university have an adequate internal capability to manage patent development? If not, should it be improved or should the university use the services of an external patent management organization?

In general, patent royalties to universities from inventions of their faculty members are an increasing potential source of income. Many universities have agreements with external patent management organization. These are generally viewed with dissatisfaction by several university administrators and scientists. In the opinion of many universities, these organizations are not sufficiently aggressive in seeking out patent and licensing opportunities, and may not be receptive to university needs. More universities are therefore developing their own internal capabilities for patent management.

Present and past experience demonstrates that patents and licensing arrangements are not real problems because university/industry research

interactions yielding specific results directly related to technical change occur rarely if at all.

Most universities allow a company sponsoring research some time to review manuscripts resulting from the sponsored research for comment to ensure that they do not contain company proprietary information. The pre-publication review period allowed varies from university to university, but it is usually not more than one year and, most frequently, one to six months. Most university scientists are generally willing to delay publication so that it can be reviewed for patent possibilities or, in some cases, for the time it takes to file a patent. Companies believe that they should have the right to review publications coming out of their sponsored research for inadvertent disclosures of company proprietary information and for potentially patentable ideas. Most scientists do not object to review for patent potential. The debate centers around the appropriate length of time for such a review. Generally, a company feels comfortable with the university owning a patent, particularly if the university is willing to provide an exclusive license for a certain time period.

In many academic fields, there appears to be a psychological barrier to interacting with industry. The more basic the research, the greater the feeling that industry will, in some way, impede the ability of the individual investigator to follow his own perceived optimal course. There is also a difference in the structure of research management in academia and industry which may cause frustrations and difficulties in cooperative research, at least in the initial stages.

In the past companies have rarely been able to make long-term commitments to university research. Short-term commitments can negatively affect the quality of a research program. At present, most companies

appear not to be geared towards planning for long-range basic research efforts.

Another difficulty from the university point of view is that industrial support tends to come in small short-term allotments, i.e., \$10,000-20,000 for one year or less. While this is not a barrier per se it does constrain some university scientists in the effort they are willing to put forth to solicit industrial funding for their research.

Moreover, there is a fear that with extensive collaboration, a university professor will be "bought" and directed away from pursuing new avenues of research. The industry opinion is that universities should be more open to appointing scientists from industry as adjunct professors. Many company scientists are interested in holding adjunct professorships. A university policy of severely limiting adjunct professorships and a lack of continuous company contributions or funding could be a barrier to university-/industry research cooperation.

Certain difficulties may exist with personnel exchange. The primary problem is disruption of family life. Second, if a company is having economic problems, it is difficult to justify this type of program. The university expresses concern that the faculty member, after working in industry, would be tempted to remain there by a large salary offer. It seems that any workable, large, formalized exchange program would have to be flexible in the length of exchange. One to two months may be a reasonable length for a good and fruitful interaction, but one year may be too long for those concerned about career development.

It is believed that industrial grants or contracts, even the very large ones, generally do not cause a conflict of commitment or interest.

Sorting out who owns what could arise in a case where several companies are supporting a generic research center at a university, while they have separate agreements with professors at the center. This can lead to complex questions of proprietary rights if a patentable discovery results from this work.

Difficulties may also arise when the research equipment used in an industrially sponsored program has been bought under federal contract, or if the federal government is still providing partial support for a university scientist's research program which also receives industrial support.

Maintenance of diversified funding sources is critical to the health of university research, though it can lead to complex accounting situations.

In discussing the development of university/industry research interactions, concern related to matters of academic freedom and research quality are of particular importance, including credibility, continuity, commingling of funds, conflict of commitment, preservation of the academy, and the importance of exploratory research. Freedom and flexibility are the backbone of the U.S. university system and are viewed as the cornerstones of its success. Resolving issues related to academic freedom can be fairly straightforward, but cases also exist where clear answers may not be available. Some of them could be situations involving conflict of interest.

Several universities are diligently attempting to develop new guidelines for faculty involvement with industry which will not compromise their flexibility or academic freedom, and have formed ad hoc committees to discuss and in some instances monitor these activities. A few universities have in fact set up guidelines for dealing with such situations. Harvard University's policy divides situations which may present conflicts of interest into three categories:

1. Activities that are clearly permissible. These include consulting arrangements which do not detract unduly from university objectives.
2. Activities which should be discussed with the chairman or vice chairman on extramural activities. These include situations in which a professor directs students into a research area from which he expects to derive financial gain.
3. Activities which present serious problems. These include:
 - a. Situations where a faculty member assumes executive responsibilities for an outside organization that would create conflicts of loyalty, and
 - b. Situations where a substantial body of research which could, and ordinarily would be carried on within a university, is conducted elsewhere to the disadvantage of the university.

The dialogue preceding establishment of useful guidelines may be strengthened by including industrial research scientists and managers.

The university must also consider several aspects of the question of credibility:

1. The capability of university scientists to be objective must be preserved by enabling researchers to diversify their funding sources.
2. In an effort to generate their own funds, universities may create situations in which their efforts are directed toward a tangible end rather than maintenance or creation of knowledge.

The question is how to devise the appropriate rules and policies for attracting or creating new sources of income without endangering the university asset of credibility. Once again, the answer lies in an estimate of balance. There is a certain level of directed research, industry or govern-

ment oriented, in which universities can engage. Each university has to evaluate that level according to its own circumstances.

In summary, most unsuccessful university/industry research interactions can be characterized by a communication gap resulting from a lack of time and effort put into building up a relationship of trust between the two parties. Despite concerns, many groups (public and private), in recognition of the economic potential of science based industries, are actively seeking to forge new bridges and linkages between university and industry.

TYOLOGY OF UNIVERSITY/INDUSTRY INTERFACE

In general, the university/industry interface can be divided into three major categories by primary objectives:

- * General Research Support: grants, donations, single contracts.
- * Cooperative Research: individual consulting, centers, institutes, consortia, industrial parks.
- * Knowledge Transfer: conferences, seminars, workshops, short courses, fellowships, adjunct professorships.

General research support from industry usually consists of industrial gifts of money (grants, donations) and/or equipment in support of university research. Most of these gifts are small, in the \$5,000-10,000 range. Grants are most frequently used to support exploratory research, or research which advances the frontier of a particular technical discipline. Direct grant awards to the university may catalyze the establishment of significant university/industry cooperative ventures. There is a growing belief in industry that by integrating such funds into a more formal research structure such as an institute or center, industry can benefit more from university research. Currently capital is tight for many American corpora-

tions and gift contributions fluctuate with the fluidity of capital. Unrestricted funds from industry are rare and/or difficult to obtain.

Normally, the initiative to establish a university/industry cooperative research program comes from within the university. However, there are many instances when a company wishes to interact with universities by hiring a consultant: a knowledge transfer mechanism. Consulting policies of universities present a wide variety of attitudes and objectives. These can vary from providing professors with a mechanism to supplement their income, to providing a conduit for bringing industry research projects into the university.

Several universities have set up mechanisms to generate consulting opportunities efficiently for their faculty. A number of universities have established centralized listings of all research interest and activities by faculty. Thus industrial firms may come to the university with a particular problem and see immediately if the university has people with the required capabilities. Also, most high technology companies, especially chemical and drug companies, have rosters of university consultants they have used in the past or are using presently.

Some schools have special programs to promote consulting activity by the faculty and others have a hands-off attitude, and still others frown upon consulting as interfering with faculty teaching and research responsibilities, without crediting any positive relationship to these functions. Concrete data on the level of consulting at universities is particularly difficult to obtain. The most common policy on consulting frequency is to permit it one day per week. In some universities, the policy varies on a school-by-school basis. In the technical units of a university, consulting activity is most prevalent in the engineering departments due to their

applied nature. The daily fee normally ranges from 0.6% to 2% of the academic year salary. Total annual compensation permitted ranges from \$8,000-15,000. Faculty must maintain a balance between their outside consulting activity and their university obligation to teach and/or research.

Increasingly, the central administrations of universities are beginning to play a role in fostering university/industry relations. Presidents who have cultivated long term relationships with industry are proving to be invaluable in initiating a center's/institute's activities. Many successful university/industry interactions have been cultivated at two levels--president to president and research scientist to research scientist.

Continuing education programs of universities can also be used to stimulate industry interest in cooperative research and knowledge transfer.

The relation with universities is often based directly on the way a particular company regards its own corporate research interest, and is structured to meet these interests. For example, most pharmaceutical companies have extensive direct research connections with universities, to the point of contracting with universities for statistical evaluation of drugs in medical school patient populations. The research personnel associated with such projects can be reallocated without affecting the basic tenured faculty pool or the academic calendar. Companies' technical problems subsequently may suggest new basic research projects.

Universities have also become more active in training entrepreneurs and supporting the efforts to create enterprises based on new technology. This includes small enterprise oriented incubation programs at various universities. Some examples are the University of Texas Chair of Free Enterprise, and also the Institute for Constructive Capitalism funded by Mobil, Shell, Tenneco and other corporations. The Center for Entrepreneurship and

Small Business Management at Wichita State University has been very successful.

In addition, many corporations are now getting together with universities to focus research efforts on areas of mutual benefit. Examples are the Center for Integrated Systems at Stanford University, corporate funding at Carnegie Mellon and Purdue Universities to study robotics, and Monsanto's agreement with Washington University focusing on proteins and peptides. Industry has not only begun to become a strong supporter of university research, it is also participating directly.

Cooperative university/industry research interactions require some degree of cooperative technical planning which may lead to the development of special administrative structures and/or research facilities such as centers or institutes.

At some universities, a substantial amount of research is done in centers or institutes, with resulting predominance of industrial support at these centers or institutes. Several successful industrially sponsored programs have occurred in centers formed in conjunction with an industrial liaison program.

The center concept brings focus to research, facilitating cooperation with industry. Though centers need not necessarily be physical entities, they must serve as a focus, providing (a) equipment in central location, (b) the necessary administrative support and (c) coherence for related research efforts conducted in a general area. They also furnish means for coordinating programs to attract industry.

Centers or institutes can be wholly within departments and schools or totally external to the university. They work best when they are under direct control of no more than a few individuals within the university structure.

There are several advantages in setting up centers or institutes. For directed research, industry generally requires a concentration of manpower brought to bear for a relatively short time in a multi-disciplinary setting. Generally, because of academic constraints, unless the university sets up external mechanisms such as centers and institutes, they cannot respond to this kind of industrial need.

Although funds in support of university research are processed in the office of sponsored programs or the development office in nearly all cases, the center's technical administration is responsible for the management and administration of university/industry programs. This includes final say on the program structure, project selection, and allocation of resources.

Many industry oriented centers now have advisory boards which include company representatives. They meet once a year to discuss policy and programs with principal investigators and center technical administration. A few of the larger programs have two separate boards: a policy board made up of industry and university officers; and an advisory board composed of company and university scientists to aid in project selection.

Usually, however, the principal investigators still have veto power and ultimate say about project execution and research mechanism. The experience of operating centers finds that university/industry programs do not work if they are administered by committee or non-scientific personnel.

The most successful interactions are almost always initiated and nurtured by a key individual who is energetic and believes that the success of the program is essential to his professional development. This individual usually demonstrates management capabilities and is recognized in his or her professional field. For a university/industry cooperative research program to be successful it must have enthusiastic faculty support.

Over 50% of industrially funded cooperative centers associated with industrial programs are less than five years old. A new feature of the industrial support of many of the centers operating now is multi-company support, including companies from several industries.

Research funding for a university program by an association of companies is of growing interest to industry as well as universities. Such interactions can include support through focused industrial liaison programs, multi-company support of a research center or laboratory, collective industry support of research, and an association of a group of companies and universities in order to conduct research.

Several universities are experimenting with fees based on a percent of sales, or at least with a differentiated fee structure for small and large companies. Universities with successful industrial programs generate from one to four million dollars annually through these programs. Less successful universities generate approximately \$100,000-200,000 in their liaison programs.

Jointly owned or operated university/industry research facilities are rare and usually take the form of research consortia. Research consortia can be characterized as specific mission programs organized to ensure that a generic or mission-oriented research will be carried out. When large consortia are directed by committees and accompanied by high administrative costs, they tend to be viewed with skepticism by both university and industrial scientists. This problem is usually related to poor program organization and management by committee.

A new development is the negotiation of long-term partnership contracts containing high level company commitments to support university basic research in return for some proprietary advantage (e.g., an exclusive

license, lead time in a new research area). The large, prestigious research universities in particular are seeking and receiving this type of support.

There are several federal government organizations supporting university/industry cooperative research efforts and one of the most effective in reaching these goals is the National Science Foundation. In helping to establish such research centers, NSF provides seed money to aid the center in commencing its research program. The objective is to encourage industry to join the program and provide increasing support. After a period, up to five years, it is expected that companies will be responsible for the complete support and financial operation of a center. Indeed, federal leveraging of cooperative funding is critical to many successful university/industry research programs.

Examples of such NSF guided/supported centers are: Polymer Processing at Massachusetts Institute of Technology, Computer-Aided Design at Rensselaer Polytechnic Institute, Welding Research at Ohio State University, Polymer Research at University of Massachusetts, Applied Polymers at Case Western University, Building Technology at Iowa State University, Robotics at University of Rhode Island, Ceramic Research at Rutgers University, Material Handling at Georgia Institute of Technology, Hydrogen Technology at Texas A&M University, Dielectric Research at Pennsylvania State University. Several university/industry research centers are in the process of being established at the University of Cincinnati, West Virginia University, University of Wisconsin, University of Arizona and University of Puerto Rico.

Another form of university/industry interaction is through joint research institutes serving industrial needs which tend to be established at public universities. Frequently, these institutes are initiated after local

industry puts pressure on the legislature to allocate state resources to form an institute to serve their needs.

These institutes most often receive industrial support or interact with companies classified within one industrial sector. Such institutes are particularly prevalent in fields related to agriculture, food and nutritional research, forestry and textiles. These tend to represent important natural resources and industrial activity of a given region, hence the emphasis within the public institution. Because of the regional focus, support of interested companies, and the strong public service mandate of the institutions where these institutes tend to be located, they provide a strong base for cooperative research activity. Currently, an increase can be noted in the tempo of state and regionally supported development activities involving academic and industrial cooperation. States significantly involved in such activities include Arizona, California, Colorado, Florida, Georgia, North Carolina, New Jersey, New York, and Michigan. They are seeking to take advantage of recent advances in the fields of microelectronics, genetic engineering and robotics.

States in economically depressed regions in which the predominant industrial base is mature are particularly interested in the creation of new jobs by fostering the development of new high technology companies with university administrators and researchers and private sector representatives playing active roles.

Many of the above mentioned activities have the long term goal of starting or expanding university research parks and/or state industrial parks.

Industrial parks in general are composed of clusters of research intensive firms and facilities on dedicated sites, often initiated by state through local tax incentives or grants and close to university research

oriented facilities. These research firms are usually private industries. The industrial park model has been developed at several major campuses to improve relationships between research-intensive companies and sponsoring universities who rent space for corporate activities. The presence of the park, in and of itself, does not necessarily strengthen university/industry research programs. But the presence of the park in successful cases has facilitated technology transfer through providing space for companies arising out of university research programs. Those universities associated with parks tend to have strong programs of university/industry cooperative research.

Many universities (Yale, Renssaeler Polytechnic Institute, Princeton, University of Texas at Austin) are currently interested in expanding existing parks or developing new parks.

Universities have many reasons for wishing to participate in the development of these parks. They include:

1. Increased interaction and easier communication between university and industry researchers helps to broaden mutual understanding of problems and needs.
2. Industry gains quicker access to new developments through increased information and knowledge transfer.
3. Industry also gains access to student workers and faculty consultants, as well as laboratory, computers, library, and other resources.
4. Increased interaction opens opportunities for creating new business and new university/industry research programs.

Examples of such industrial parks are: Stanford Industrial Park, North Carolina Research Triangle Park and Florida Industrial Park, to mention

only a few. Research parks such as the Research Triangle in North Carolina are usually established with some initial funding from the state government.

ROLE OF THE CENTER FOR ENERGY AND ENVIRONMENT RESEARCH IN THE UNIVERSITY/INDUSTRY INTERACTIONS IN PUERTO RICO

In September 1983, in response to growing demand for scientific assistance from Puerto Rican industry and recognizing the reasons stated previously, the university of Puerto Rico undertook the initiative to organize a University/Industry Cooperative Research Program. A visit was made to the National Science Foundation to seek information and guidance.

Three steps became evident - the need to:

1. Identify interest, expertise and hardware available within the University of Puerto Rico System;
2. Identify industries and their needs, and the extent to which they would support the formation of a University/Industry Cooperative Research Program; and
3. Determine if matching exists between industry needs and research expertise and hardware available at the University.

During the period September-November 1983 visits and discussions were conducted with chairmen of Departments and Deans of various campuses of the University of Puerto Rico and also with individual scientists/researchers to identify existing human and hardware resources, and the specific areas in which the University has strong programs.

As the result of the preliminary UPR resource assessment, pharmaceutical, chemical, petrochemical, food and cosmetic industries were selected as the initial target industries for the University/Industry Cooperative Research Program.

On November 29, 1983 a meeting was held with industry representatives to discuss the general concept of a University/Industry Research Program. At the suggestion of industry representatives, a joint University /Industry Task Force was formed to work toward establishing a University /Industry Research Program in Puerto Rico. Five industry representatives and seven university representatives were named to the Task Force. Task Force industry representatives recommended that a University/Industry Research Center be created in Puerto Rico to implement the Program. In the ensuing 9-month period several meetings with the Task Force industry representatives, industrial companies, university Deans and research faculty took place.

Altogether 35 companies were introduced to the Program and some 30 faculty expressed interest in participating in the Program research activities. Many of the faculty are researchers in the School of Pharmacy. As the result of these meetings and discussions, 15 companies expressed interest in the program and sent 11 letters of support. The pharmaceutical industry is the most committed to the Program with 9 companies strongly interested in participating. Analysis of Puerto Rican industry needs vis--vis university resources indicates that a good possibility exists for establishing a University/Industry Research Program oriented mainly toward the pharmaceutical industry in Puerto Rico. Other interested industries could also receive advice and assistance under this Program later on.

Under such a Program industry seeks institutional responsibility, continuity and permanence as well as high quality results obtained in a timely manner. In exchange industry is ready to support financially such an arrangement and to commit itself to several years of continuing co-funding.

To fulfill industry and University needs and interest a joint proposal was submitted to the National Science Foundation by the School of

Pharmacy of the Medical Sciences Campus and the Center for Energy and Environment Research to request a planning/study grant to establish a University-/Industry Cooperative Research Program in Puerto Rico.

The proposed Program will give participating companies an opportunity to leverage their research funds by providing access and right to a large interdisciplinary research program for a fraction of the total cost, thus making the Program cost-effective. The Program will provide pharmaceutical industry professionals with an opportunity to participate directly in research through extended visits and to update their knowledge through attendance at seminars and short courses.

The concept is unique in Puerto Rico in several respects. It envisages academic and industrial cooperation in the area of pharmaceutical and related chemical research; provides industry with new research opportunities; provides a means of transferring scientific knowledge from the University of Puerto Rico to industry; makes possible the transfer of some research related to Puerto Rico pharmaceutical industry operations from the U.S. mainland to Puerto Rico; and makes the science (university) and technology (industry) interrelationship more synergetic. The concept also offers new research and training opportunities for both partners and additional research funding for the University, and creates new employment opportunities for graduates, thus reducing the brain drain of professionals to the U.S. with its negative impact on the economy of Puerto Rico.

Finally, by offering an effective university/industry research infrastructure, the Program will reinforce Puerto Rico's industrial promotion program offering new high technology companies an additional incentive to set up operations in Puerto Rico.

The Center for Energy and Environment Research took the initiative and acted as a catalyst in activating University (UPR), industry and federal government (NSF) interest and preparing a proposal in September 1984, to the National Science Foundation requesting a planning study grant.

Earlier, in August, 1984, special Commission established by the governor of Puerto Rico recommended in its report the establishment of an Industrial Research Park in Puerto Rico and also the establishment of a Center for Science and Technology as the focal point of such a Research Park's activities. The Commission was first proposed in a preliminary study on the subject prepared by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico in January 1984. CEER personnel acted as the Secretariat for this Commission.

Four sites were recommended as suitable for the establishment of this Center and the Research Park. They are:

1. University of Puerto Rico property next to the Rum Pilot Plant in Puerto Rico.
2. The eastern industrial park in Dorado.
3. Land property of the University of Puerto Rico next to the Ramey Air Force Base in Aguadilla.
4. University of Puerto Rico property adjacent to the UPR Campus in Mayaguez.

At present the Center for Energy and Environment Research conducts, jointly with industry, the educational activities of the Summer Science Student Program. This Program is funded totally by the private sector including SK&F Lab. Corp.; Syntex Corp.; Merck, Sharp & Dohme, Inc.; Pfizer Pharmaceuticals, Inc., Shell Oil Company; Union Carbide, Inc.; Caribbean

Refrescos, Inc.; Lifesavers, Inc.; Banco Popular; Banco de Santander; Wang Laboratories, Inc; and Westinghouse Education Foundation.

CONCLUSION

Factors essential to getting a more successful cooperative arrangement between university and industry can be summarized as follow:

1. A high commitment by both faculty and high level administrators at the university to the concept of creating a recognized university research facility.
2. Commitment by local industry to utilize the strength of the university and at the same time honoring university objectives.
3. Maintaining a degree of flexibility in university policies and organization to allow development of university based industrial research without compromising the academic mission of the University.
4. Identification of a strong leader highly respected by the academic and industrial community to establish and maintain the university/-industry partnership.
5. Matching the needs, interests and resources, both physical and human, of both university and industry.
6. Commitment of industry to provide a continuous funding of the joint research program.

The University of Puerto Rico and one of its research arms, the Center for Energy and Environment Research, are thus moving in the direction of establishing closer ties with Puerto Rican industry.

The University of Puerto Rico has made a commitment to become a first class research university and industry could play an important role in these aims. The University System 10-year development plan clearly leads toward this goal. In June 1984 the Foundation for Higher Education was established

by the Council on Higher Education which also recently appointed a Higher Education Committee to foster graduate education and the establishment of more graduate programs. At present only eleven Ph.D. programs exist, this situation could change dramatically, however, if Puerto Rican industry were to join the University to boost graduate research. The assistance of various research units already operating within the Puerto Rico University System could enhance cooperative university/industry research endeavors. As noted above, units such as Center for Energy and Environment Research have been able to play the role of a catalyzer in relations between UPR and Puerto Rican industry and have started new initiatives. These initiatives, leading toward the establishment of the University/Industry Cooperative Research Program, have met with favorable response from the Puerto Rican industry. The federal government represented by the National Science Foundation has also expressed strong interest. Finally, the support of the Council on Higher Education and the President's office have once again confirmed the importance of the involvement of the administrative forces to foster university/industry cooperative efforts.

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