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ABSTRACT

Proceedings of a 1980 workshop on industry/university cooperative programs are presented. Program presentations and authors include: "On Industry/Academia Relations" (T. Baron); "The MIT Liaison Program" (J. D. Bruce); "An Industrial Perspective of Academic Programs" (R. Fuller); "University/Industry Interactions through 'Centers'" (R. L. McCullough); "Industry/Academia Interaction in Polymer Science and Engineering at IBM" (J. Economy); "Observations on Industry/University Interactions in Animal Health Research" (D. C. Farrington); "Industry/Academic Interaction in Polymer Science and Engineering at Case Western Reserve University" (J. Lando); "Industry/Academia Interaction in Materials Science and Engineering at Rockwell International" (P. Cannon); "University/Industry Coupling: Philosophical Underpinnings and Empirical Leanings" (R. Roy); "Master's Degree Program in Computer Science Under Contract to a Large Electronics Firm" (W. H. Matchett); and "Philadelphia Association for Clinical Trials: Review and Prospects" (J. Schrogie). In addition, introductory remarks are presented by James C. Seferis, Michael Pelczar, Fred Betz, and Paul V. Tebo. The introductory remarks focus on the incentives and problems that may be anticipated in initiating and participating in industry/university cooperative programs. The majority of speakers and participants emphasized that in order to foster cooperative activity in research and education, it is necessary to institutionalize short-term and long-term communications between university and industrial personnel. (SW)

Industry / University Cooperative Programs

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Industry / University Cooperative Programs

Proceedings of a workshop held in conjunction with the 20th annual meeting of the Council of Graduate Schools in the United States

December 2, 1980

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Sponsored by The Council of Graduate Schools in the United States and the National Science Foundation

Workshop Chairman Prof James C Seferis Industrial Affiliate Program Department of Chemical Engineering University of Washington

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Preface

A workshop examining industry university cooperative programs was held December 4, 1980, at the 20th Annual Meeting of the Council of Graduate Schools in the United States. Sponsored jointly by the National Science Foundation and the Council, the workshop brought together participants in a variety of such programs from both industrial and academic institutions. Presentations describing existing and developing programs representative of interaction at different levels of the institutional structure were solicited in order to provide a broad spectrum of experiences and perspectives from which the benefits accruing to the partners of such programs could be elucidated. With the recent increased interest being expressed by both industry and academia in effecting working partnerships, the workshop provided a timely forum to an audience (the Graduate School Deans) whose members ultimately become involved in these activities. It is important to recognize, however, that industry university cooperative programs have as their main goal the enhancement of scientist-to-scientist interaction. Thus, sponsorship of the workshop by the the NSF Industry University Cooperative Program, which is designed to enhance such one-on-one couplings of university and industrial researchers, was significant in sharpening the workshop's focus on cooperative programs that encourage interaction at this level.

The workshop was put together by a program steering committee whose members selected appropriate presentations, provided background material, and directed discussion during the workshop. With their assistance, a one-day program that focused on industry academia liaison activities in general terms, as well as on selected areas of science that have enjoyed good industrial support and participation, was defined. Presentations and discussion periods, which formed an integral part of the workshop, were both taped and transcribed. Following in this volume are edited papers submitted by the speakers based on the transcripts that were provided to them. Following these papers are selected general questions that were put to the speakers during the workshop that capture for the reader the essence of some of the exchanges that took place during the workshop. I feel that together, these papers and selected speaker audience exchanges will provide the reader with an excellent collection of case studies of "state of the art" for industry academia collaborative programs. In putting together the workshop and this volume, I have counted heavily upon the assistance and support provided by the members of the steering committee, the Industrial Affiliate Program of the Chemical Engineering Department at the University of Washington, as well as other personnel and services of the University. I am also very grateful to Dr. Michael J. Pelczar, President of the Council of Graduate Schools, and Dr. Fred Betz, Director of the IUC program of the National Science Foundation, for their continued interest in and support of the workshop.

James C. Seferis
Workshop Chairman

Introduction

Unquestionably, this workshop, focusing on industry university cooperative programs, addresses a timely and important area that promises to become an integral part of an industry's or university's operations. The program descriptions and ideas put forth by the participants provide a wealth of information and experiences from which one can draw in setting up or redirecting existing cooperative programs. Having been through the process of developing such a program recently at the University of Washington, I have attempted in this overview to point to some common features that emerged from the various contributions that are essential for the success of these cooperative ventures. In doing so, I have attempted to direct the reader's attention to the various programs that are described in this volume and highlight some of the unique concepts and ideas put forth by the workshop participants.

The introductory remarks of Drs. Pelczar, Betz, Tebo, and myself were designed to bring into focus some of the incentives and problems that may be anticipated in initiating and participating in such programs. The stage having been set in the introductory remarks for the workshop from industrial, governmental, and university points of view, the majority of the speakers and participants emphasized that in order to foster cooperative activity in research and education, we need to institutionalize short- and long-term communications between university and industrial personnel. Although a formal internal program by an industry may not be necessary to promote such activities (an opinion expressed in the presentation by Dr. Baron of Shell), the advantages of having an institutional program at the university are clearly shown in the MIT program described by Dr. Bruce. In the MIT program description, one can observe the strong commitment of a university to integrating liaison activities with industry compatible with its structure. Dr. Bruce's comments captured in the question and answer section of the proceedings also emphasized the importance of understanding and distinguishing three basic ingredients that may be found in cooperative activities with industry, these being, (1) collaborative research in specific areas of science. (2) knowledge transfer mechanisms and exchanges, and (3) philanthropy.

Dr. Fuller's presentation demonstrated the existence of all these ingredients in describing activities at Johnson & Johnson and further gave weight to Dr. Baron's comments that the interest of an industry in collaborating with universities is in basic education and research. ingredients that are already imbedded in any university's charter. Dr. McCullough's description of the Center for Composite Materials at the University of Delaware, a program focusing on a specific area of science, demonstrates that a program at the college level can be successfully incorporated as an integral part of a faculty's regular academic duties. He views industrial input through the program into faculty activities as a valuable component in identifying basic research problems and educational goals.

Industry/university cooperative programs in specific areas along traditional discipline lines are described in the presentations that follow. These encompass the life sciences (Dr Farrington, Pfizer Co. and Dr. Jacobson, Iowa State University): polymer engineering and science (Dr. Economy, IBM, and Dr. Lando, Case Western Reserve): and materials (Dr. Cannon, Rockwell International, and Dr. Roy, Pennsylvania State University). In addition, contributions by Dr. Matchett (New Mexico State) on setting up a Master's degree program in computer science and a unique concept of collaboration in the medical field by Dr. Schrogie (Philadelphia Association of Clinical Trials) provide insight into the details of initiating programs in specific areas. In particular, what emerged from the presentation of Dr. Farrington, who addressed the control of animal disease, is that a close collaboration between industrial, university, and governmental entities must be maintained. Similarly, Dr. Jacobson, who put into perspective the activities in the life sciences arena at Iowa State, describes long and fruitful collaborations with industry in this area. In the polymer engineering and science area, the collaboration between industry and academia has traditionally been strong as a result of many scientists coming into academia after having worked in industry for quite some time. Both Drs. Economy and Lando clearly emphasized the importance of scientist-to-scientist interaction in addressing some key problems in the future development of this field.

Because of its interdisciplinary nature and economic importance, industry/university collaborations in the field of materials have a long and successful history, and its participants can count, in their ranks, people like Drs. Roy and Cannon. Unquestionably, the contribution by Dr. Roy in this volume gives the reader an intellectual perspective of university/industry couplings as well as a framework for systematic discussion. Dr. Cannon's contribution, on the other hand, provides an equally challenging analysis of the individual nature that must be maintained in all industry/university relationships.

In summary, I believe that the reader will find a wealth of information on industry/university collaborative programs presented in this volume. If a main theme can be drawn from these contributions, it is that industry is assuming an increasing share of the burden in supporting higher education, generally to the benefit of both. Although several presentations do make the case that these relations are better developed without government participation, the examples are numerous in which assistance by government provides the necessary catalyst for initiation of and continuity in these relations. In particular, for young faculty just starting their careers, both an institutionalized and established program of industry/university liaison can facilitate their initiation into collaborative research.

In addition, such programs provide accepted modes of operation within universities as well as needed visibility in the industrial sector. One should remember that an orderly and well established mechanism of support exists from government, with the peer review system fairly well accepted in the academic ranks of all disciplines. On the other hand, in the absence of well-established channels of communication of faculty with industry, a new faculty member can be asked a classic question if he seeks funding from an industrial source: "We do not know your work, your capabilities, and you have no track record. Now, what was it you were proposing to do research in"? Clearly, long standing perceptions of industry/academia relations will have to be altered. My hope is that this workshop and resulting proceedings will have taken a small but significant step in providing incentives and encouragement for more industry/university cooperative activities.

James C. Seferis
Workshop Chairman

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Introductory Remarks

Dr. Michael Pelczar

President, The Council of Graduate Schools in the United States

It is a special privilege for the Council of Graduate Schools, in conjunction with the National Science Foundation, to take part in arranging for this workshop. Industry/university cooperation is a very timely issue, and I hope that it isn't just a passing fa icy or a tad. I don't believe that it is. I think that industry/university partnerships or relationships have existed for many years in many different forms. Some have been very successful; others have not been. But I think that we are in an era in which a new look at what is being done and how it is being done, at what kinds of arrangements have been successful and what kinds have failed (and why they have failed) is needed. We hope that the exchange that we have planned for today will result in a definition of the manners or modes of interaction that are successful. We can develop some documentation even beyond this workshop that eventually can be distributed to persons in industry and in academia who are in positions not only to participate but also to benefit from such arrangements.

This workshop was put together pretty quickly, but I think all of the parts are in pretty fine tune now, and we anticipate a successful day. Jim Seferis from the University of Washington; Jim Bartoo from Pennsylvaina State University; Paul Tebo from E. I. du Pont de Nemours & Co.; Dan Zaffarano, the chairman of the Council of Graduate Schools' Board; Jerry Daen and Fred Betz from the National Science Foundation deserve the credit for the planning that has gone into putting this workshop together. Let me conclude my welcoming remarks by reading a short quote from a very famous scientist—Dr. Carl Haskins, formerly director of the Carnegie Institute who, in a report entitled "Public and Private Science," had the following to say about the tripartite arrangement of government, industry, and colleges: "The tripartite arrangement is almost uniquely developed in America and can be of unique strength and effectiveness. It has been the envy of the world, and, clearly, one of our great challenges in the years ahead will be to make it work better to achieve greater permeability, more effective feedback, and better coordination among its components, and to preserve the integrity and the effectiveness of the whole. Understanding the tasks of each, recognizing their capacities, and, above all, preserving an appropriate balance among them and promoting their optimal synergism in the interest of the nation—these are the basic tasks for today and tomorrow."

I would underscore that this is our task *today*. Again, welcome to the workshop, and I look forward to a very successful exchange of ideas and information.

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Dr. Fred Betz
Director, IUC Program
National Science Foundation

I'd like to review briefly the recent history of the federal government's concern about industrial-university relationships. During the last decade there has been concern at the national level about the United States' ability to continue to innovate and to compete internationally and about the appropriate role the federal government should play in fostering industrial innovation. This is both a complex and a delicate issue because while the federal government is not a producer of goods and services, or knowledge, it has a significant stake in the success of those who do. Accordingly, it is important to encourage cooperative attitudes among the three sectors of society—industry, academia, and government.

In 1975 the National Science Foundation began trying to define an appropriate role for itself with respect to basic research in industry. After several meetings and committees the Director of the Foundation created a program called the Industry-University Cooperative Research Program. Its purpose was to encourage closer industry-university relationships by sponsoring cooperative research projects between industrial scientists and university scientists. In this way, the Foundation could provide support for formal cooperative projects which, in terms of a broad spectrum of support of such projects, was not otherwise available. At the start of this program it was decided that the primary criteria for funding a project would be the quality of its research, and that we would prefer—to the extent practicable—to leave the administration of the programs to the participants. This has worked, I think, fairly successfully.

Some of the lessons that stand out in our experience are rather obvious, in retrospect. But things are usually clearer in hindsight. First, it is the high technology industrial sectors that use science directly and in so doing supply the basis for future technology, that participate in the program. Secondly, it's in these scientific areas that technological questions pose important questions for science. Consequently, there is a very close coupling between technology and science for the high-technology sectors of industry and the areas of science which directly couple to technology. These terms science and *technology* delineate more clearly the nature of the university/industrial relationship. Industry is technology intensive; universities are science intensive. In the areas of economic activity where science and technology directly interact, cooperation is natural and important.

Much of the science policy discussion at the federal level has centered on the terms *basic*, *applied*, and *developmental* research. I think that we will be seeing in this next decade a shift to the terms science and *technology*, because, in my view, this clarifies the situation when the national concern is about the relationship of science to industrial innovation.

The reason the Foundation is sponsoring this workshop is that it will be important to the nation over this next decade for industry and academia to define even closer relationships with each other in ways that are natural and do not divert the historic mission of the universities in education and the generation of knowledge, and that presume that industry should always be working toward a long-term profit motive, increasing productivity and innovation. Today I hope we can clarify an important part of the cooperative problem: what can university administrations do to encourage and facilitate relationships between industrial scientists and university scientists for (1) the increase of knowledge, (2) the furtherance of education, and (3) the use of knowledge in industrial innovation.

Dr. James C. Seferis
Director, Industrial Affiliate Program
Department of Chemical Engineering, University of Washington

I should like to add a few words to these introductory remarks concerning what academia is seeking in its interaction with industry. Although the first thing that comes to a person's mind is funding, I think that the primary incentive in establishing a cooperative arrangement with industry is to have an input for updating and evaluating in a meaningful fashion our basic educational and research objectives. Financial considerations, of course, will have to be put in perspective, but in my mind these will have to come as a result of the interaction and should not be the primary motive for setting up collaborative programs with industry. The programs and activities we want to talk about today fall into a category of institutionalized arrangements that universities make in providing a particular focused service to industry and in soliciting input from it. Such activities are often formally organized under the titles "industrial liaison" or "affiliate programs" and are created and administered at the university-wide, college, or departmental level. We have speakers today who will describe details of such programs. We trust that we will hear from our academic speakers as to how these programs impact the university's objectives as well as affect the individual faculty and students involved in such programs.

My experience and that of my students has been gratifying in having industrial input to our work. We also find that close collaboration with industry provides an added dimension of importance and usefulness in the work we do. In general, however, because of traditional differences existing between industry and university, cooperative programs must clearly provide answers to certain fundamental issues that arise as a result of such couplings. For example, to certain people from academia, the cliche of industrially funded research not being "academic" research but rather an activity based on financial considerations alone is a perception that can impose significant barriers to industry university collaborative efforts.

In putting together the announcement for this workshop, the steering committee identified some of the issues that need to be addressed specifically in any program that promotes university/industry interaction. These were—

a. faculty consulting and proprietary information
b. impact on research quality and on young faculty development and promotions
c. industrial interests: charity vs. service
d. disciplines most likely to develop such programs
e. optimum structure and organization of the programs
f. impact on graduate enrollment
g. program continuity and survival

Although this list by no means is intended to be exhaustive or all-encompassing, I hope that the issues it comprises will be addressed by the workshop participants. Thus, rather than elaborating further on each of the above issues, I will let the speakers provide answers to these through the descriptions of their programs.

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Dr. Paul V. Tebo
Engineering Technology Laboratory
E I du Pont de Nemours & Co

The topic of industry/university programs is of particular interest to me, mainly because of du Pont's wide-ranging interactions with the university community: We have been, for instance, a member of affiliate programs such as those at the universities of Washington and Tennessee; have had professors in residence in our organization from six weeks to more than three months; and have engaged students as summer employees (one West German student spends time with us each year). We are also in the process of submitting a joint proposal with Princeton to the NSF for studies in the area of rheology.

Rather than limit these remarks to personal opinions on the benefits of our industry/university programs, however, I should like to present the results of a modest survey among companies that participate in the University of Delaware's Center for Composite Materials. Eight of the member companies responded (companies such as du Pont, Ford, Celanese, General Electric). Professor Byron Pipes, Director of the Center, was most helpful in implementing the survey. Let me stress that this small sampling of opinion is not statistically significant. The responses are offered only to stimulate our thinking and to set the stage for the discussions to follow.

The survey asked two questions: (1) Why does industry participate in joint university/industry research programs? and (2) What guidelines do participants use in selecting a particular university or program? Answers were grouped, according to frequency of response, into top, middle, and bottom categories.

Question number one involved ranking several alternative reasons for participation on the basis of their importance to the responding company. The top answer was clearly the importance of having qualified people trained in technical disciplines related to the present and future business areas of the industrial sponsor.

Three reasons fell into the middle category: enhanced interaction with university faculty, value of the research being conducted, and interaction with students as a recruiting aid. It is interesting that three companies chose value of the research as their number one reason for participation (and one ranked it seventh). Also, the recruiting aspect is often singled out as a prime motivation for industry participation. Yet the survey would indicate that, although important, recruiting is not the major consideration.

Falling into the bottom category were interaction with other companies in areas of mutual technological interest and enhanced company goodwill.

These low rankings were somewhat surprising. Goodwill is important to most companies, and interaction with other companies has always emerged as a prime benefit of the joint consortium. University/industry programs afford opportunities for companies to discuss technical developments of mutual interest in an atmosphere divorced from business considerations.

A few general comments on question one should be made:

- According to Professor Pipes, many companies joined for one reason but later found other reasons to be more important.
- Company size showed no correlation with the responses.
- The survey was answered by technical management having responsibility for R&D budgets and specific research objectives, rather than by corporate "educational aid" administrators whose interests are in the areas of unrestricted and young faculty grants.
- Although the importance of training qualified people differs from that of recruiting, the two are related.
- Recruiting and company goodwill are the prime reasons behind corporate aid (unrestricted grants).

The response to question two indicates that there are no formal guidelines for selecting a particular university or program. However, the most frequently mentioned guideline was the *quality of the faculty*, followed by the availability of facilities, the quality of proposed research, and the quality and breadth of co-sponsors.

Other guidelines mentioned on one or two responses were the quality of students, the efficacy of the program as a recruiting aid, cost, new ideas, and rapid growth of technical competence in areas new to the company.

Some of the answers to question two also were surprising. Cost to the industrial sponsor does not seem to be a significant criterion at this time. The most expensive program that we are aware of (MIT's polymer processing program) is equivalent only to the cost of supporting one person for one year in industry. Conversely, I had expected that the "new ideas" criterion would have been higher on the list. This topic might be worthy of further discussion today.

Let me re-emphasize that this brief survey cannot prompt any definitive conclusions. Many industry representatives here undoubtedly have still other opinions on how and why a company becomes involved in a joint program with one or more universities. Furthermore, we have not touched upon two other important questions:

- What key characteristics separate a successful program from an unsuccessful one? For instance, how important are the aggressiveness and capabilities of the program director?
- What technical area characteristics are most amenable to joint industry/university treatment—fundamental versus applied, broad or narrow, long-range versus near-term?

I am most interested in hearing about other persons' experiences with joint industry/university endeavors. Such programs will surely escalate, and, with this growth, the research capabilities of both partners will be strengthened in the process.

Program Presentations

On Industry / Academia Relations

Dr T Baron, President
Shell Development Company

Good morning. I'm not really sure why I'm here. I'm not very qualified to speak on the subject. Nor do I feel that we are addressing a burning issue. I disagree with a previous speaker who said that things as great as the fate of national innovation is at stake. It may well be true that the United States has fallen behind others in certain areas in innovating. I don't think that has anything to do whatever with the people in this country who innovate. I don't think that university people are less brilliant today than they were in the past. I don't believe that people in industry invent less than they used to. I think that if there's an innovation problem it's a sociological and political problem having to do with the relationship between government and industry and especially the anti-industry attitude of our previous administrations. I hope that this will change now. I don't think, therefore, that improved cooperation or improved interaction between industry and universities will affect such important national problems, nor do I think that the universities need to be greatly improved by contact with industry.

I am an employer of the product of universities, and I must say that I am always amazed at the excellence of that product. We employ engineers, chemists, geologists, physicists, mathematicians, you name it, and all these people coming from major research universities in the United States have a preparation that in my opinion leaves nothing to be desired. No, I hope that whatever we do in the future will not deteriorate things as they are. I can't think of any improvement that's desirable from this point of view, nor can I think of any improvement that is desirable from the point of view of improving basic knowledge that this country or the world will make use of and, therefore, my company will make use of. If you think of what might well be the future industries twenty to a hundred years from now, the two big things that come to mind are chips and the things that come from that, robots and so on, and then the new biology. Heaven knows what will come of that, but I would think that that is going to be one of the foundations of many great industries in the next decades. It cannot be denied that American universities have pioneered in these fields, and I don't see any threat or any lessening of the energy with which things are pursued.

So that speaking now purely as a customer of what universities have to offer, I must say, ladies and gentlemen, that I couldn't be more satisfied. That's why I am little puzzled about why I'm here. It should be for them to state what the problem is, if there is one. I have, however, some good friends at universities, and I suspect that there are some serious problems having to do, first of all, with funding. Now this is a very complicated and difficult problem. It is unfortunately clear that in our society students cannot provide all the monies required to support education and research in our universities; industry doesn't seem to be capable or willing to, and the federal government is making up the difference. I don't think that anything we do today will change these facts. I would like to say, however, that from my point of view I would welcome any step that would increase the funds coming from industry, and I think that any activity devoted to a better understanding of how these funds can be made available—or should be made available—so as to least shackle the people at the University is a welcome activity.

Let me illustrate what I mean. I'm mainly worried about any method of disbursing funds that will, in a sense, corrupt the intent of university work, which is both education and unfettered pioneering research to be judged by peers not a priori—before it is done—but a posteriori—after it has been done. Bear in mind this definition and this objective. One of the difficulties that arises today is when people at universities ask professors to seek outside funds, a lot of the professor's time is spent looking for funding for proposals. Some of the proposals come through. But they may not come through in time for participation in the research by the students they were intended for. These students may already have graduated, so a certain amount of shifting and juggling of funds has to be done, all of it providing a slightly corrupting influence. I don't mean corruption in the legal sense, but corruption in the sense that it perverts the basic idea of university participation in such an activity. We at Shell have tried something for just the first time this year that I hope will be successful, but only time will tell. We have started to found some distinguished chairs in which a professor is awarded by the university, not by Shell, a chair for a five-year period. During that period his salary is paid, and enough money is provided each month to pay his graduate students so that he does not have to seek funds elsewhere or so that he certainly can minimize the funds that he seeks elsewhere.

Will this prove to be useful? Well, we hope it will; only time will tell. In any case, I think that one of the major purposes of industry/university interaction should be to provide funds to the universities with a minimum of perversion of the essential purpose. Now, besides just providing funds, industry can, of course, interact in other ways with universities, and here again my plea is that this interaction preserve the integrity with which this process should and must go on. So I don't think that what counts is so much what is done, but the purpose and the integrity with which it is done. A given thing can be successful or unsuccessful depending on what is in the hearts and minds of the people who are engaged in this interaction. I would think that it should be extremely important when a university or industry starts such a cooperative effort to keep this in mind.

Let me tell you a little story of what happened in our own company that will illustrate why I'm a little worried or why I want to approach this question with great trepidation and the greatest degree of care. We have a department at Shell Development Company whose job is to provide new chemistry that will be the foundation of the next significant research events in Shell, the other departments being the ones managing the current projects. But some of my directors and department heads said, "But is it all right if we use these people as consultants?" and I said, "Well, yes, of course it's all right. I mean these people are here, and we're not going to keep you from talking to them." So it was agreed that it was okay to go to them.

Several years went by after we founded this department before it came to my attention and to the attention of my top senior managers that although the department was functioning well and producing things of major importance, it somehow wasn't performing quite as well as we had hoped. Furthermore, people in the department felt that the original purpose for their group really was not being achieved. What had happened was that consulting relationships had started immediately, and people would go to these scientists and ask them if they knew a way to do this or to do that, and the fellow would say, "Well, yes, I think I do but I'm not sure. Let me make a few experiments." And pretty soon, well over half of the department was engaged in work that was completely unintended. The focus of their work shifted from long-range to short-range; and being very clever chemists, the more successful they were, the more they were in demand. We completely perverted the process, mind you, in a situation that was totally under our control. A university/industry interaction will never be under anybody's control.

This is what I am afraid of, and so my plea to you is that the sanctity of the process be guarded as much as possible, that a university/industry coupling should not be undertaken for the purpose of transferring funds or for the purpose of seeking funds. On the other hand I do believe that there are legitimate situations in which universities need cooperation with industrial research, and, I think, really, this should be the criterion: Does the university need it? And this will be in the area in which the professors involved have great personal interest that is rather close but general to an area in which a number of industries are involved. One, for instance, in which Shell is involved and which is very useful to us, is the University of Delaware Catalytic Research Center. Here's a case in which I believe that the motivation of the people of the University of Delaware is that they want to do chemistry that happens to be on that frontier from which great companies or small companies might easily draw ideas. They need us because they need to see how we react and to know what we think is important and unimportant. They want their students to become interested in industry because they know that this kind of research, this type of knowledge, will ultimately be used in industry. So they are really thinking of this as fulfilling interests of their own. Now if that is assured, then, of course, the sanctity of the procedures is assured, and I know of no problems whatsoever. Every now and then I ask the fellows if they're learning anything from this process, and the answer's always "yes," so we keep supporting it. Presumably the university likes it as well because they also continue with it. I would say then that the first important thing is the motive. The second most important thing is the scale. I think that universities should not undertake things on a very large scale. I have had universities approach me that wanted to develop a coal gasification process and ask if I would be interested in supporting it. I would say no. Why? Because I think at least a billion dollars will be required to develop one of them. They don't have the manpower. If the whole university did nothing but work on it, they wouldn't have the manpower. So the scale has to be reasonably modest within the scope and capability of a university.

Well, I could go on, but I would just like to emphasize in summing up my comments that I think that things are okay. There is nothing wrong with American universities. I think that anything that industry can do to increase the amount of funding going to the universities is great, and that we should do it. But we should do it in such a way that it does not pervert the essential purposes of a university. If the university wants to do things for which they need an atmosphere in which they can understand industry better, then one way is through the kind of cooperative effort we've been discussing. I thank you for inviting me.

The MIT Liaison Program

Dr. J. D. Bruce, Director
MIT Industrial Liaison Program
Massachusetts Institute of Technology

I am very happy to be here with you at the CGS/NSF Workshop on Industry/University Cooperative Programs and to have this opportunity to describe MIT's Industrial Liaison Program. My remarks will be divided into two sections. First, I want to describe our program and how it works, and second, I want to suggest several reasons why it has been so successful and thereby to indicate prerequisites for the establishment of similar programs.

MIT's Industrial Liaison Program was founded in 1948. Its objective is to provide efficient and timely access to the research and staff resources of the Institute for the benefit of its members. The program helps fulfill a founding responsibility of MIT to industry. As stated in its charter, issued by the Commonwealth of Massachusetts in 1861, MIT's purposes include ". . . the advancement, development, and practical application of science in connection with arts, agriculture, manufactures, and commerce. . . ." Currently, over 270 companies belong to the program, including some 40 in Europe and 25 in Japan.

MIT is a large, diffuse organization. The Institute includes 23 academic departments, organized into 5 schools, and over 40 interdepartmental/interdisciplinary centers and laboratories. The Institute's research budget will exceed $300 million in the current fiscal year. Its research programs and staff thus represent a tremendous potential resource for industry and commerce. However, it is difficult, or perhaps even impossible, for a company to gain efficient access to the wide spectrum of the Institute's resources without having some special link to MIT. The Industrial Liaison Program provides one such link, creating an effective interface between MIT and member firms through a variety of services.

Key to these services in providing a productive relationship between MIT and a member company is the liaison officer. The officer acts as the member company's personal representative at MIT. In this role, the officer is charged with actively focusing the company's relationship with MIT to assure maximum exposure to those Institute activities that can be of value to the member company.

Currently, there are fourteen full-time liaison officers associated with MIT's program. Each has an advanced degree, and usually at least one of the officer's degrees will be from MIT, or he or she will have had research experience at MIT. Liaison officers have a variety of technical backgrounds, including mechanical and electrical engineering, nutrition and food science, materials science, chemistry, chemical engineering, physics, civil engineering, aeronautics and astronautics, psychology, and management. Additionally, each has had several years' experience in industrial or university positions. These officers are experts in their respective technical fields and on MIT, and they develop comprehensive understandings of the interests and needs of the organizations they serve. For example, each officer regularly travels to the principal locations of the firms he serves, learning about company interests, meeting company personnel, and describing the ways a member company can make use of the program. During each year every officer spends about 20 percent of his time away from MIT, traveling to member company locations throughout the USA, Canada, Europe and the Far East.

The industrial liaison officer also is responsible for personally supervising and encouraging the use of the many services offered by the Liaison Program. In these and all activities, he is supported by his fellow officers (in fact, each member company has a "back-up" officer in addition to the officer with principal responsibility for the member company) and, of course, by the MIT faculty and professional research staff.

Discussions with Professors and Research Staff

The most valuable resource at MIT is its faculty and staff. Many are respected worldwide as distinguished experts with extensive experience in industrial problem solving arising from their research activities, private consulting, and, in many cases, past industrial employment. The Liaison Program provides two important ways in which member organizations interact directly with this resource.

First, there are visits by company staffs to MIT. Whether a member company's interest is in pharmaceuticals. microwave devices, polymers, microprocessors, financial planning, solar energy, energy policy, food preservation and marketing, or whatever else, it is likely that MIT has science, engineering, or management faculty doing research in that company's area of interest and who would welcome the opportunity to review the field or discuss their research with the staff of that company. These visits offer excellent opportunities to review problems and new ideas and for MIT researchers to exchange views with their professional counterparts in industry. In addition, the liaison officer is often called upon to recommend faculty experts for in-depth consultation on specific problems a company might have. In such instances, financial arrangements are made privately between the company and the faculty consultant. During the past year, over 2,500 visits occurred between member-company staffs and MIT faculty.

Second, MIT faculty and staff travel widely and often are able to extend their journeys a day or two to permit them to visit one or more member companies. Such visits may include seminars or informal discussions and provide an effective way of "bringing MIT to the member." Each year over 250 visits are arranged at no additional expense to the members. These visits are to locations throughout the USA, Europe, and Japan.

Directory of Current Research

To keep our member organizations informed as to the research work under way at MIT, the Industrial Liaison Program publishes the *Directory of Current Research*. This directory, updated annually, is the most comprehensive summary of MIT research programs available. Abstracts of over 2,500 research projects are listed in the 1980 directory.

The directory serves as a handy reference that may be used to search out those research projects in which one is especially interested. A bibliography on each project, as well as manuscripts and preprints of papers submitted for publication, abstracts and documents, laboratory progress reports, working papers, internal technical memos, etc., is available from our office.

In addition, each month the Liaison Program mails the *Monthly List of Publications* to key individuals and libraries—approximately 9,000 mailing points—in each member company. Listed in this publication are the titles of 80-100 documents—with abstracts—that we believe will be of interest to member-company staffs. Any of the reports listed can be ordered from the Industrial Liaison Office by returning a response card. The monthly list also announces MIT patent awards and applications, as well as other programs likely to be of interest to our members.

Symposia

Major research efforts at MIT, of special interest to members, are reported at one- and two-day symposia held at regular intervals throughout the year. Some 12-15 such meetings are held each year. The titles of recent meetings have included—

- Advances in Modern Control Theory
- Computer Graphics
- Management of Research, Development and Technology-Based Innovation
- Solar Energy Utilization—Possibilities and Probabilities
- Biotechnology: Status and Prospects
- Future Demand for Energy
- Materials Research
- Office of the Future
- How Microprocessors Are Changing Product Design
- Toxicology Research
- Polymers Research
- IC Engine Operation Fundamentals

A detailed program outlining the symposium presentations is mailed to member companies about six weeks in advance of the meeting so that there is time to combine the trip to Cambridge with other business. Some of these symposia are held in cities around the country so that distant companies find it more convenient to attend. For instance, we have recently taken a symposium on "Intelligent, Optical Videodiscs and Their Applications" to Los Angeles, and another on "Management of R&D and Innovation" to San Francisco. Typically, 100-150 people attend each meeting. Symposia offer good opportunities to review the latest developments with other experts in the field in the university's informal atmosphere.

Seminars

Reports on more specialized research efforts at MIT are presented at a series of informal half-day programs. Examples of some recent seminars include—

- Review of European Aerospace Activities
- Nondestructive Evaluation of Fiber Composites
- Nutrition and the Brain.

These seminars generally involve one or two speakers and an audience of about thirty. Being on a smaller scale than symposia, seminars have a flexibility that allows a sharper focus on the specific topic. The meeting can be held near potentially interested member companies, and topics and location can be selected to maximize the benefits to companies in the geographical area where the seminar is being held. In addition to seminars in the U. S., the Liaison Program regularly schedules programs in Europe and in Japan, where 19 were offered last year.

Special Foreign Programs

Expanding membership abroad has prompted the development of programs especially designed for member companies in Europe and in Japan. For example, we maintain an office in Tokyo to enable us to provide more timely service to our Japanese members; intensive short courses have been held in Europe for several years, and courses stress topics where MIT has special expertise in areas of particular interest to European industry. A similar series of programs for Japan is being planned.

Summary

In summary, the ILP at MIT offers—

- Systematic and efficient access to the results of research supported by a budget of nearly $300 million without investing in the research, creating a most valuable supplemental research resource.
- Opportunities for individual discussion with knowledgeable, leading experts who have already digested the relevant background materials, who can make a focused response to inquiries, and who can focus a discussion of the relevance of their research activities to specific company interests and problems.
- Creation of close professional ties with MIT experts, providing a resource that can prove extremely valuable. Such ties can be most important when special consulting needs exist or when a company is recruiting highly trained staff.
- Ability to efficiently monitor the progress of technologies and development that may be of current or long-range interest to the member company, and which may significantly influence its current business or suggest important new business opportunities.

Now, permit me to turn to the second issue I promised to address: Why is MIT's Liaison Program so successful? I believe there are three basic, equally essential reasons. First, MIT regards its program as a service—not a fund-raising—program; second, there exists at MIT an ample, broadly ranging base of research to support a liaison program; and third, the MIT faculty is eager to develop and maintain contacts with industry. Let me elaborate on each of these points briefly:

- Although it reports to MIT's Vice President for Resource Development and does raise over $4,000,000 per year, the central thrust of the Liaison Program is to provide its members with access to MIT's research results, not to raise funds.

Our aim is to work with our companies so that they obtain significant business benefits from their ILP membership.

- With some $300 million in research under way annually—ranging from basic, fundamental studies to, for example, process development—in fields ranging from architecture to (almost) zoology, that is from A to Z, it is extremely likely that first-rate work is being done in a number of fields of central interest to many companies. They find MIT's work to be stimulative, to be suggestive of new products and processes, and to provide a check on work under way at or of interest to the company. We find that our members do not limit their contacts to any one department, laboratory, or research group, but rather seek contacts widely across the campus. And, while their contacts are primarily with our faculty and research staff, there is an increasing number with administrative and service staff dealing with topics as wide-ranging as our energy conservation program, our nonunion grievance procedures, and the importance of documenting a company's history.
- MIT faculty have a long history of interaction with industry. Some of this interaction has led to the founding of highly successful companies. Essentially, all of our faculty are active consultants—Institute policy encourages them to spend up to one day per week for their personal, professional activities. Faculty participate in the Liaison Program because it provides them with far broader contacts with industry than they would otherwise have. They find this contact beneficial in planning, in carrying out their research, and in keeping their teaching activities current.

I might note at this point that during the 1980 fiscal year, just over 700 of our 950 faculty were active participants in the Liaison Program's activities. When you take into account those faculty working in fields that are not of principal interest to industry, this is indeed a very high figure.

To recognize our faculty's participation in serving the members, we share 10 percent of our gross revenues with them. This involves an elaborate point system to track each faculty member's interaction with ILP member companies.

These funds do not represent additional income to participating faculty, but rather are available for the faculty member's "professional development." In recent years these monies have supported graduate students in areas that were unfunded, have purchased laboratory equipment, have paid professional society membership fees, have subsidized travel to professional meetings that would otherwise not have been possible, etc.

Now, in closing, a word of caution to you who are considering establishing such programs. The countryside is littered with programs that have failed. My experience is that if you start a program primarily to raise money, it will inevitably fail. If you do not have a strong research base, it will fail. And, if you do not have faculty committed to the concept and willing to spend time, it will fail. However, if you have the prerequisites, I know of no better way to develop strong, lasting institutional relationships with industry.

An Industrial Perspective of Academic Programs

Dr R Fuller, Vice President
Academic Relations
Johnson & Johnson Company

When Dr. Seferis invited me to speak at the symposium, I had only recently assumed my current role with our company. I was excited at the prospect of my new assignment as Vice President of Academic Relations because of my interest in industry/university collaboration during almost twenty years of industrial research involvement before assuming general management assignments. I was both surprised and encouraged by the current emphasis on the subject of industry/university relationships. I think there is now a widespread recognition within industry that we have a big stake in the health of our universities and, particularly, in protecting and encouraging their basic research activities.

Although with the best of intentions, federal government support of research is tending more and more to impose constraints on time and to demand specific, quick, and usable results. The effect on research, I believe, is more cautious design of experiments, a drift toward safe and sound projects, and less inclination among researchers to gamble on risky ideas. As Senator Moynihan of New York wrote in an article entitled, "The State vs. Academe," in a recent issue of *Harper's* magazine: "The federal dollar is tempting, and in the absence of other means to mount an important project, the compromises become easier and easier to make." He concluded that the conquest of the private sector by the public sector, of which Joseph Shumpeter wrote a generation ago, continues apace: "If the private institutions of America [in this case he was referring specifically to the universities] are to be preserved, we are going to have to defend them."

Fortunately, the roster of corporations and universities engaged in some type of cooperative effort is already impressive. Most of you are aware, I am sure, of the recently announced MIT-Exxon program, the Harvard-Monsanto agreement, the Bristol-Meyers grants for cancer research, and the recently announced twenty grants from IBM to department chairmen at science universities to spend at their own discretion. These are just a few of the programs, many others of which are of a more modest nature.

After all that has been written lately, in both lay and scientific publications, it's almost impossible to discuss anything new or unique in university/industry relations that hasn't already been reported somewhere. Accordingly, I thought it best to simply stick to the announced purpose of the workshop, which is to describe and analyze experiences of industry/university liaison activities. I will therefore describe briefly some of our company's attitudes, actions, and expectations with respect to our relations with the university community.

Interaction with and support of academic institutions is not something that has suddenly come about for our company, nor for many other companies. What we are currently seeing is an increased emphasis on the need for more and better university/industry cooperation after a long period of relative indifference to one another. Johnson & Johnson and many other corporations have a long history of support in various ways for our academic institutions. This support includes capital grants for instructional facilities, endowed chairs, scholarships and fellowships, matching grants for unrestricted gifts to universities by company personnel, and support of special projects. For us, such support is part of our family of companies striving to meet its social responsibilities according to the principles set forth in our Credo, which was first introduced almost forty years ago.

The Credo is a timeless document; it's pretty idealistic in its goals, but is pragmatically effective when its principles are put into practice. Its author, General Robert Wood Johnson, evidenced remarkable vision when you consider that it was in the mid-1940s that he foresaw the critical need of our corporation to embrace its responsibilities in the many communities where we live and work. The Credo articulates the company's responsibility to "participate in promotion of civic improvement, health, *education*, and good government" and, significantly, I believe, mentions this separately from its articulation of the company's obligation to support good works and charity. I point that out because I do not consider that support of education is a charity. It's not a charity, it's a responsibility. Good teaching, particularly of science, demands good basic research that seeks new knowledge and understanding. This is a fundamental reason for industry to support basic research activities. We depend on the universities to educate the personnel we need to staff not only our R&D facilities, but also many other parts of our business. Thus, support of university basic research activities can properly be viewed as enlightened self-interest.

What are some of the incentives for industry to participate in industry university cooperative activities? If long-term investments in basic science are not continued and, in fact, perhaps accelerated, industry will find itself without the information required as a basis for the development of new technologies and products 15 or 20 years from now. It's worthwhile reflecting on the recent explosion of activities seeking practical applications for the new hybridoma and recombinant DNA techniques. The basis for these developments goes back a long way. Hybridomas are a late, long-deferred product of the discovery of the phenomenon of cell fusion, which became possible itself only after many years of perfecting cell culture methods, including cultivating myeloma cell lines. For genetic engineering, there is more than thirty years' background of research in virology and molecular genetics, most of it done in the absence of any idea that recombinant DNA would result from it. We need to continue to deposit new data in our bank of stored information, or, as sometimes happens in personal life, we will find our future requests for withdrawal stamped NSF. For those of you who may never have undergone such an unfortunate experience, perhaps I should explain that NSF stands for "not sufficient funds." Perhaps I should say NSI for "no such information," so there will be no confusion with the sponsor of this conference.

Industry can and does benefit from interaction with university researchers because of the intellectual stimulation this provides. It is an essential way for scientists to keep up with current progress and is a source of ideas and inspiration. which do not necessarily have to be product-oriented. It thus contributes to the competence of the industrial scientist so that he has the capacity to respond effectively to the opportunities provided by new scientific advances.

Obviously, there are other ways in which industry/university liaisons benefit industry: the use of professors as consultants. contract work carried out on specific projects for industry, cooperative research programs and access to university technology and patents through industrial liaison programs such as we've heard described, and through licensing and royalty arrangements. Industry sometimes provides the venture capital for entrepreneurs to develop opportunities coming from university research activities. Our various companies are involved in all such types of arrangements. A valuable interchange is accomplished through lectures and seminars, both those given by academicians to industry and those given by industrialists to the university community. We have a program of invited speakers from universities and stage symposia on specific subjects. Some of our scientists hold adjunct professorships and lecture at universities. This is not developed to the extent that I believe it could be. Such interchange goes a long way toward improved understanding and removes many of the imaginary barriers to communication between us.

Another excellent interchange has been accomplished by some universities and companies that have provided sabbatical leaves for professors to work in industry and for industrial researchers to work at universities. We've had very little experience with this type of interchange, but we have plans to develop it further. During the past year we negotiated an interesting arrangement in which the director of research at one of our companies was given a tenured faculty appointment as a senior scientist (equivalent to the professorial rank) at a university. This calls for him to devote 50 percent of his working time and effort to a joint research program. He shares the direction of the laboratory set up for this purpose with a full-time professor at the university. He will continue to devote the other 50 percent of his time to the direction of our company's research program. While it took almost a year from the first conception of this idea to the final agreement, there was great enthusiasm from both parties because each felt the need for knowledge and strength the other could provide. Naturally, there were problems to be worked out with regard to publication, patent rights, and royalty arrangements; but when both parties have agreed on the value of the relationship, these things have a way of being resolved without compromising the essential norms and values of either party. Unfortunately, this program has not been in existence long enough for me to give you a meaningful report on its progress, but we are extremely optimistic about the value of this innovative approach.

Also, during the past year, our company has carefully reviewed its total contribution program. In an article in *Nation's Business*, Mary Tuthill observed, and I quote, "Instead of spreading contributions far and wide perhaps to whomever comes through the door, hat in hand some forward-looking corporations are using narrowly defined programs to try to improve the world they function in. This kind of thoughtful planning could make corporate philanthropy more potent." This is exactly the course we have decided to follow in establishing our "focused giving" program. While a major share of our contributions will continue to go to worthy charitable and community causes, a significant portion of the monies available will now be directed to the support of basic research in universities. Because of our position as the broadest-based company in the health-care field, it follows that the research efforts we will support will be in that area.

The program is not short-term oriented or specific-project oriented, and the support will be ensured for a minimum of three and, more likely, five years. There is no contractual commitment, and the company will not have exclusive rights to any information or patents that may result from the research. The essence of the company's interest is to bring its people closer to those at the university, a goal which we feel will bring benefits to both parties.

In an article in *Science* in 1972, Rustum Roy, who will address us this afternoon, spoke of industrial fellowships as typically tax-deductible corporate gifts to the university, extremely valuable as general support for a department or laboratory in themselves, but involving no research interaction whatsoever. He even suggested that such a corporate "gift" was dangerous for research interaction because it tended to support an idea in many an industrial research manager's mind that university departments are looking for handouts rather than delivering value for money. He concluded that fellowships from corporate headquarters are gifts to the university, and if they are to be a means of interaction, they should be transferred to the research vice president who could use them as a means of nucleating research interaction. We believe that the key to effective interaction between universities and industry is scientist-to-scientist contact and interaction on research programs of common interest as expressed by Prager and Omenn in their *Science* article in January of this year. My situation is interesting because I represent the corporate headquarters, and I do not want to fall into the trap described by Dr. Roy. Because of the highly decentralized nature of our corporation, with each of many companies supporting their own R&D activities, my challenge is to select basic research activities that are related to our interests in the health-care field and which parallel or complement activities within one or more of our independent companies. I am working with the various company research directors to accomplish this. This does not mean, however, that there is any intent to direct the research or that it be structured to obtain specific results. The objective of the program might best be viewed, as I stated earlier, as one arising from enlightened self interest and the recognition of the importance of fundamental research discovery as the foundation upon which the future applied research and development activity within our corporation will depend.

Another important aspect of the program is its flexibility.

We are not wed to any particular type of support, so we can respond to a wide variety of ideas and opportunities. I think it is significant that the chairman of the board, who conceived this idea, created my current position as vice president of academic relations so that adequate time and attention could be devoted by someone with both a research and business background to establish a meaningful program. Expected return to the company from this program is at the very least the satisfaction of having discharged our social responsibility in a productive way, because through careful selection we will have supported a worthwhile research activity. There is little doubt that it will enhance our reputation as the leading company in health care, but just as we heard earlier in the survey, which was reported by the first speaker this morning, this is not the prime reason that we have established the program. It will allow professors and students to better understand us and industry in general, and this will increase, we hope, the possibility of talented researchers being attracted to an industrial research career. There's a very real possibility that down the road the basic research that we have sponsored may trigger some commercial opportunity that may result in a different type of interaction with the universities, such as a grant for a specific project or projects. The closer the ties between our research scientists and those in the university, the more likely is the relationship to bear fruit. Anything over and above the accomplishment of the objectives of sponsoring some worthwhile research and establishing a better communication between our research communities and our managements, I view as an extra bonus that would be very welcome, but not essential, for the program to be considered successful.

Unfortunately, this program also is a very new one, and I cannot give you an appraisal; however, it has been favorably received by the research community within Johnson & Johnson and in my discussions with the various universities. I am impressed with the universities' sincere desire, not just to get funding to supplement or replace government support, but their real desire to establish more meaningful links with industry.

I'd like to conclude my remarks with a few observations and suggestions from my experience to date. Dr. David of Exxon said in an interview regarding its new program with MIT, "Every arrangement has to be custom tailored to suit the specific company and the specific university." This suggests that any program should be as flexible as possible so that it can be structured to be beneficial to both parties. While the alliance between the corporation and the university has obvious benefits to both sides, it also represents the joining of two cultures with each bringing into the partnership differing values, objectives, and expectations. Any arrangement must not compromise the principles or basic functions of either partner. The university's independence, without which it cannot serve society responsibly, must be maintained. Fortunately, unlike government, private corporations do not have the capacity to follow their money with coercive regulations that would restrict a university's independence. Our experience to date suggests that when the partners have the proper motivation and the desire to collaborate, any problems presented by the essential requirements of both parties can be overcome.

There is room for much more industry involvement with the universities, as Tom Baron said this morning, and specifically in basic research support. Latest figures indicate only three percent of all university basic research is supported by industry. A positive note is that in the past three years corporate giving rose an average of sixteen percent annually—faster than giving by any other sector of society. I believe there is an opportunity to direct more of this into programs such as our company and others have initiated. I'm sure all of your universities have industry representatives on your boards who can help in getting some of the increased industrial giving directed to this very important area.

A note of caution, however, and here I strongly second the remarks of Tom Baron: We must be careful not to replace the tendency towards more directed, safe research implicit in some government funding by short-term, results-oriented research for industry sponsors. I believe that there is a place for such work in the university, but it should not become so extensive as to adversely affect the basic research activities that the rest of society looks to and depends on the universities to carry out. I'd like to make one other. somewhat unrelated, but important, point. It appears that the legislation assigning patents resulting from government-sponsored work to the university will be approved. This should aid in getting patented developments commercialized by industry because of the possibility of exclusive licensing arrangements. I hope that the universities will not dissipate this advantage by insisting, as they often do, in excessive up-front payments rather than relying on fair royalties once the technology has been converted to a marketing reality. There usually is a very large investment needed for development and some uncertainty regarding its ultimate successful completion. If the up-front cost is too high, this combination of factors can discourage an industrial management, and the idea may not be developed. I encourage you rather to seek any rewards primarily through royalty arrangements, which reward both partners for their contributions.

I think two quotations will provide a fitting close to my remarks. The first is from *Chemical and Engineering News* of November 3rd, this year, commenting on the report of the National Committee on Research on industry and universities: "The commission cautioned against rushing headlong into it. Universities should not make the same unthinking mistakes they made with government, the report warns. Industry and universities need each other; the relationship can be productive and innovative, but only as long as both parties maintain their independence and special intellectual creativity." The second is on a more personal note and deals with my current assignment. It was said by Aristotle 2300 years ago: "To give away money is an easy matter and in any man's power, but to decide to whom to give it and how much and when and for what purpose and how, is neither in every man's power nor an easy matter."

University / Industry Interactions through "Centers"

Dr R L McCullough, Associate Director
Composites Center
University of Delaware

Thank you for inviting me to this conference. I suppose my major function will be to describe how a relatively small university with limited resources has managed to participate in coupled industrial-academic programs. I will restrict my comments to our College of Engineering, which has essentially three research institutions: the smallest being a recently formed Division of Durability; The Center for Catalytic Science and Technology, which was discussed earlier today; and the Center for Composite Materials. Also, the Institute for Energy Conversion is allied with the College of Engineering and is the largest of these groups. Each of these organizations has a unique character. I will concentrate on the Center for Composite Materials.

The principal programs are polymer processing and rheology, micromechanical analysis, anisotropic stress analysis, microstructural characterization, mechanical characterization, and computer-aided design methods. The current focus is on the polymer processing/rheology area and the micromechanical analysis of fiber-reinforced materials. We have developed characterization techniques as well as new computer-aided design methods as part of an ongoing research program. The major objectives of this program are to develop and maintain research facilities and to enhance the cooperation both within the faculty as well as with industry. Also, we are using this program to help us focus our research and teaching activities by identifying new and emerging areas that we should be incorporating into our special courses as well as identifying new areas of research that faculty should be investigating.

The growth of the Center has been exponential. We started our activities in composite materials in 1973 with small, individual grants on the order of $30,000. We formed the center in 1974 and attracted more funding. In '75, '76, and '77 more funds came from the Navy and DOD-type agencies. In

'78 the industrial program was initiated with an increase of the budget of up to $400,000. Support is now in the neighborhood of $700,000-800,000 yearly.

Figure one suggests the variety of faculty involved. Dr. Byron Pipes is director of the center; he is associated with Mechanical and Aerospace Engineering Department. I am the associate director and am associated with the Chemical Engineering Department. We have faculty involved from Mechanical Engineering, Chemical Engineering, and Civil Engineering.

FIGURE 1

Personnel Associated with the Center

FACULTY

R. BYRON PIPES Director; Professor of Mechanical & Aerospace Engineering, Ph.D. University of Texas
SPECIALTY: Mechanical property characterization and finite-element methods.

JACK R. VINSON Professor, Mechanical & Aerospace Engineering, Ph.D. University of Pennsylvania
SPECIALTY: Analysis of plates and shells.

ROY L. MCCULLOUGH Associate Director, Professor of Chemical Engineering, Ph.D. University of New Mexico
SPECIALTY: Anisotropic mechanics of short fiber composites.

COSTEL D. DENSON Professor, Chemical Engineering, Ph.D. University of Utah
SPECIALTY: Processing of polymers.

ART B. METZNER Professor, Chemical Engineering, Sc.D. Massachusetts Institute of Technology
SPECIALTY: Rheology and fluid mechanics.

JEROLD M. SCHULTZ Professor, Chemical Engineering, Materials Science and Metallurgy Faculty, Ph.D. Carnegie Institute of Technology
SPECIALTY: Structure and properties of polymers.

THOMAS W. BROCKENBROUGH Professor, Civil Engineering, SM Massachusetts Institute of Technology
SPECIALTY: Fiber-reinforced concrete.

ROBERT L. NICHOLLS Professor, Civil Engineering, Ph.D. Iowa State University
SPECIALTY: Composite materials in construction.

Jeffery W. Edington Professor, Mechanical & Aerospace, Materials Science and Metallurgy Faculty. D.Sc.
University of Birmingham, U.K.
SPECIALTY: Electron microscopy.

Herbert B. Kingsbury Associate Professor, Mechanical & Aerospace Engineering, Ph.D. University of Pennsylvania
SPECIALTY: Solid mechanics, vibrations, visco-elasticity.

Morton M. Denn Professor, Chemical Engineering, Ph.D.
University of Minnesota
SPECIALTY: Fluid mechanics and rheology.

Minoru Taya Assistant Professor, Mechanical & Aerospace Engineering, Ph.D. Northwestern University
SPECIALTY Micromechanics.

Tsy Wei Chou Professor of Mechanical and Aerospace Engineering, Ph.D. Stanford University
SPECIALTY Fracture Micromechanics.

PROFESSIONAL STAFF

Ralf Tschirschnitz B.S. Electronic Physi[illegible]Salle

Dale W. Wilson B.ME. University of Dela[illegible]e

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Robert A. Blake M.EE. University of Delaware

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Mark A. Deshon B.S. Graphic Design. University of Delaware

The major thrust area is the application of composite materials to industrial products, with most of the effort aimed at the automotive industries. A list of our current industrial sponsors is shown in figure two. Each company contributes $30,000 a year (with increases expected in the years to come to account for inflation) in support of the program. The range of companies include both users and suppliers. In response to one of the questions that was raised earlier today about good, small companies really participating, I wish to point out the participation of the Rogers Company.

One of the key points in developing any such program is to recognize the need for strong facilities with modern (expensive) equipment. Our major facilities are summarized in figure three. We developed funds for these within the university and did not rely on our sponsors to supply the modern characterization tools or process equipment vital to any on-

FIGURE 2

Current Industrial Sponsors

Celanese Research Company
E. I. du Pont de Nemours & Co. (Inc.)
Ford Motor Company
General Electric Company
General Motors Corporation
Graftek/Division of Exxon Enterprises, Inc.
Hercules Incorporated
ICI Americas, Inc.
International Harvester
Owens-Corning Fiberglas
PPG Industries, Inc.
Rogers Corporation
Xerox Corporation

FIGURE 3

Facilities

PROCESSING: Injection, Transfer and Compression Molding Facilities

CHARACTERIZATION: Fatigue, Creep, Anisotropic Properties, Viscosity, Dynamic Mechanical Impact

NONDESTRUCTIVE EVALUATION: Ultrasonic, Mini-computer, Thermographic, Acoustic Emission

COMPUTER-AIDED DESIGN: Computer Graphics, Dedicated Mini-computer

ENVIRONMENTAL SENSITIVITY: Accelerated Environment Facilities

GENERAL: Machining Facilities

going research program. One of the major facilities we had to develop to allow us to carry out mechanical testing was an extensive characterization laboratory. That laboratory is completed and is available for research and teaching activities. In addition, in the area we are dealing with, processing studies are vital. These materials are very sensitive to processing, variations in processing can change material characteristics and give considerable variability in behavior. Processing studies must be coupled with performance studies; the two cannot be separated. We are developing extensive processing capabilities both for injection molding and for compression molding techniques. In figure four I have included current research for federally supported programs. The point to contrast between these two programs is that the industrial program is somewhat less directed and less oriented in specifics than is the federally supported program.

FIGURE 4

Current Research

1980 FEDERAL PROGRAMS

- **Compression Fatigue of Notched Composite Laminates**
- **Flaw Criticality and Nondestructive Evaluation of Composite Materials**
- **Metal Laminate Research Program**
- **Damage Repair Technology in Composite Materials**
- **Behavior of Composite Bolted Joints**
- **Effect of External Plasticizers on Carbon Fiber Composites**
- **Glass/Phenolic Short Fiber Composites**
- **Failure Modes in Short Fiber Thermoplastics**
- **Properties of Hybrid Composites**
- **Fracture Based on Transformation of Strain**

SPONSORS

Naval Air Systems Command
National Aeronautics and Space Administration
Air Force Office of Scientific Research
Naval Research Laboratory
Department of Energy
National Science Foundation
Army Research Office

All the industrial research programs are reviewed by the techniques suggested by Dr. Baron, and I will discuss that process in a moment. A major contribution from our program, and a surprise I think for most faculty, has been the composites design encyclopedia, which we issue in ring binders each year to our sponsors and for which we issue supplements each year. The encyclopedia currently comprises five volumes, one volume each on mechanical behavior, analytical design methods, processing technology, failure analysis, and design studies. A sixth volume on computer models is proposed. Characterization data must be available for the design of components made from this material. Analytical design methods is a rich area for theoretical research and mechanical analysis; mathematical tools are being developed to handle these complex systems. Failure analysis and material science are important. Processing science is vital. We also provide certain case studies.

This document is partially written by outside consultants. We felt that we needed to give something tangible to our sponsors. We did not want to divert all our faculty's time to compilation of the encyclopedia, so part of our funding went to hire outside experts and consultants to help us write the design encyclopedia. We have found that this has been probably one of the most useful undertakings of the Center. It provides a clear focus, helps to identify gaps in research where new, basic research programs can be directed, and helps to define future research goals. Secondly, it has provided the faculty with new insights. Many of the faculty are now participating in writing the design guide. I have elected to become an author, as well as have several other faculty, because it satisfies something we have been wanting to do for some time and have not had a ready mechanism to do it: namely, to organize data, to organize ideas, and to organize knowledge. I believe that this has been a very useful exercise for the faculty. It also serves to help in teaching students, in that they can refer to articles in the design encyclopedia to supplement their normal textbook material.

Instruction is a vital part of the program, as has been suggested by several of the previous speakers. The efforts in instruction have included course offerings and workshops, and industry intern program. Our sponsors early on indicated they felt this was important—not so much as a recruiting tool—but to provide industry with expertise in this emerging technology. We have developed new courses and modified old courses to accommodate this area. Each January we hold a workshop for our sponsors, and our graduate students attend it as part of the program. We have a university's intern program whereby sponsors can send a person to spend a year working in our laboratories on their own research projects and interacting with the faculty. We also have a mechanism by which faculty, and students as well, can spend time in industrial laboratories.

We also have instituted an advisory board in the Center for Composite Materials. Each company has two representatives who serve on this board. The board meets once or twice a year to review progress and to review proposals for research. Our faculty (those who might be interested in having a graduate student supported or in having summer support for themselves) write brief proposals defining their intent. The proposal is submitted to an advisory board that ranks the proposals, not so much in terms of the scientific content or even the faculty member's reputation, but in terms of the value of that piece of work. The director, associate director, and other selected people review these rankings. There is a tendency, of course, to try to maintain our research effort consistent with our sponsors' needs. However, we have on occasion funded low-ranking projects because we felt, even though the companies were not uniformly enthusiastic about these projects, that they were vital to a given area. This work has been well received by our sponsors, and I think our decisions have been correct. The advisory board does not direct the research; it advises us and helps us to rank areas. Another important function it serves is to help to keep us from repeating work that is already available within industry but has not yet been published.

Membership in the Center is not restricted. Anyone who has a technical contribution to make can join. The word *technical* is important and tends to limit membership to companies that can contribute to the interactions with the research—not just the funding. Again, the key point here is that we desire strong interactions with our advisory board and with members of industry.

Finally, I would like to comment on the Center's productivity. Since 1974 the Center has turned out over 60 research publications and reports. We have now graduated 100 students in mechanical and chemical engineering who have participated in enrichment programs, written senior research theses, or taken special elective courses in the area of composite materials. We have turned out 20 Master of Science and 7 Doctor of Philosophy degrees with special training in the area of composite materials. I might add that Ph.D. students are rapidly absorbed by industries moving into this area. We have expended close to two million dollars and have developed a little under a million dollars' worth of facilities.

Observations on Industry / University Interactions in Animal Health Research

Dr D O Farrington Manager
Animal Health Research
Pfizer Company

Successful development of tools for the control of animal disease or for improved performance involves a close interaction of industrial, university, governmental, and animal industry entities. Each partner in the process has its own perspective, but the ultimate objective of aiding the animal producer to effectively and economically produce livestock is the same.

According to figures released by the Animal Health Institute (AHI), the national trade association for the major United States manufacturers of animal health products, net U S sales of animal health products exceeded $1.7 billion in 1979. This includes sales of pharmaceuticals, biologicals, and feed additives. AHI member firms (approximately 50) invested more than $125 million to finance research and development in the animal health field in 1979 (approximately 7 percent of sales). This represented a 17 percent increase over 1978 R&D expenditures. About $25 million (20 percent) of the 1979 research dollars were spent on "defensive" research in response to government requests for additional research on already approved products. Seven percent of the R&D dollars (about $8 million) were spent in foreign countries for products destined for U.S. markets. Forty-one AHI companies have approximately 1,700 scientists working directly in animal health research. As can be seen from the preceding information, a substantial research effort (with very limited budgets in relationship to the sums spent on human health) is being made, and opportunities for development of improved or new cooperative research interactions are present.

Industrial animal health research tends to be intensely project oriented, with large resource allocations being expended in the specific areas being investigated. Research objectives within these broader project areas change often as compounds move from discovery to developmental stages or are rejected, as they may be for a variety of reasons. The challenge for a university program interested in industry interaction in the area of animal health is to quickly identify the specific ongoing project areas in industry in which university investigators also have expertise. An example would be disease models that can be applied to drugs that companies have in the New Animal Drug Application (NADA) approval stage. Also, industry discovery research project teams generally collaborate with university investigators who have models or field expertise not usually available in industry.

Animal Health Industry Considerations

An excellent working relationship exists between industrial and university animal health researchers. Many of these individuals have similar backgrounds and are products of the same professional and graduate school systems. This close relationship has evolved over a long period of time and has required a great deal of effort and understanding from both parties.

There is some industry concern, however, about the general lack of knowledge of industrial research realities, motives, and objectives among university researchers and administrators. As previously mentioned, much industrial research is directed towards compliance with government regulatory procedures and is initiated with stringent protocols. This "defense-oriented" research limits resources for new discovery-oriented investigations, stymies innovation and creativity, and is generally considered to be boring by most investigators. Proposed government actions in the area of Sensitivity of Methods (SOM, the system FDA is proposing for determining just what a "zero" residue is when considering a cancer-causing substance) and cyclic review (FDA's proposal for a process under which existing products would be reviewed to find out if data on file meet current standards for human safety research) may further retard new discoveries in animal research. The implementation of Good Laboratory Practices Regulations in animal health research also has added a crushing amount of paperwork to carry out simple use animal experiments. The GLPs will impact the university directly when collaborative work is undertaken. Additionally, the approval of thoroughly researched beneficial medicinals is often delayed years for no substantive reasons, resulting in a costly drug lag. In addressing these industrial animal health research realities, university investigators and administrators can play an important role in developing a strong third-party position in mediating the over-regulation environment currently prevailing in animal health research. Industry motives inevitably seem self-serving when objections are raised. The interests of industrial and university scientists would seem to be mutual when combating forces that threaten new animal drug research, shrink the number of drugs available to the veterinarian, and raise the costs of livestock production.

Industrial funds in most university, animal health research projects tend only to complement the researcher's program. An awareness of the complex problem of industrial influence on university programs must be constantly maintained in order to avoid the perception that the university is just an extension of industry testing programs. Finally, from an industrial perspective, important realities are that funds are not unlimited and that its research effort must eventually result in useful, marketable products.

Some Methods for Facilitating Industry/University Research Relationships

University, college, or departmental research review programs for representatives from industry have been successful in generating the development of cooperative research projects. Industry funding of projects with multiple objectives beneficial to several parties (e.g., university, animal industry, industry) is often desirable due to the scarcity of funds from other sources for animal health research. Strong connections can be built and maintained in these areas of mutual interest, resulting in better continuity of university programs.

The establishment of a contact individual for identifying and facilitating research activities between university investigators and industrial research programs (e.g., college level research dean, industrial university liason director) is an essential requirement for developing the mutual trust and interest required to maintain a good. long-term relationship. Meetings should be organized at the university among high-level industrial research executives and college deans and department heads for discussions of areas of possible cooperative research. Presently, considerable individual scientist interaction is taking place. but a commitment to the concept and implementation of industry/university cooperative research projects must be made by the responsible administrators Also, the initiation of an active program of visits by university researchers to industrial research organizations, with emphasis on the commonality of interests, can be beneficial. University investigators often are surprised by the depth and extent of industrial research efforts and by the company interdisciplinary cooperative activities in progress.

Industry/University Cooperative Research Model

Existing industry/university interactions in the animal health research field can serve as a model for developing other successful partnerships. This is particularly evidenced in the situations where university discoveries are commercialized by industry (e.g.. a new vaccine). Basic discovery and predevelopment research at the university can receive industrial support via "memorandum of understanding" documents. This memorandum would include rights of first refusal to patentable discoveries and ensure a smooth technology transfer to industry for possible commercial development and testing. Developmental research leading to federal licensing would prepare the discovery to meet the test of the marketplace as a useful and desirable product. Royalties can accrue to the university based on the product's commercial success and can be used for support of further worthy nonfunded research projects.

Industry's Support of University Research

Dr N L Jacobson
Animal Science
Iowa State University

Industrial funding of university research in the U.S. declined sharply from the 1950s to the 1960s. This was due in part to the relative ease with which federal grants could be obtained in the 1960s. A 1978 report prepared for the National Science Foundation stated that industrial support of basic research in universities (industry support as percentage of the total) declined from 10.9 percent in 1953 to 2.1 percent in 1966. Thereafter, a slight increase to 3.0 percent in 1977 occurred.

A recent issue of *Chemical & Engineering News* contains a special report presenting similar trends for industry's share of academic R&D support and predicting an increase from about 2.7 percent in 1968-72 to 3.5 percent in 1978-81 (Figure 1).

The 1978-79 Annual Report of the Council for Financial Aid to Education shows that total voluntary support increased substantially during the past two decades. When calculated as a percentage of the total expenditures by colleges and universities, the trend is similar to the trends in research funding presented above—a decline from 13.5 percent to 6.0 percent over the 20-year period from 1957-58 to 1977-78.

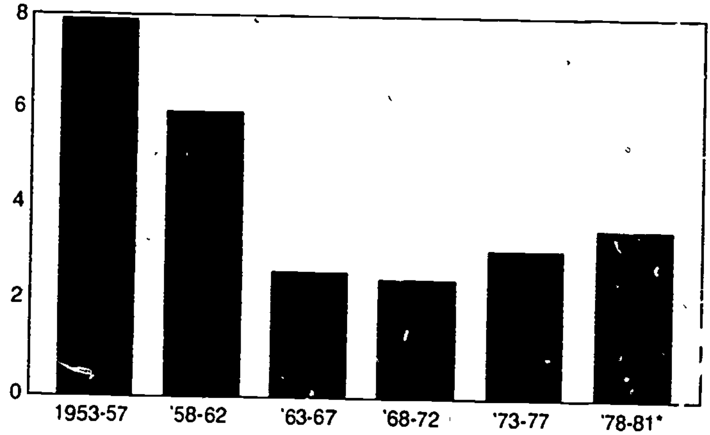
Recently, the need for stronger linkages between industry and its scientists and the universities and their scientists has been much discussed. There have been many studies and numerous reports emanating from various sources. Federal funding agencies have been encouraging ties between universities and industry. Since 1978 NSF has been making grants for university/industry projects and expects to spend $15-16 million this year for cooperative ventures. The Departments of Commerce and Transportation have programs still on the drawing boards to stimulate university/industry cooperation.

There are those who believe a growing state of disenchantment between industry and universities exists. Indus-

FIGURE 1

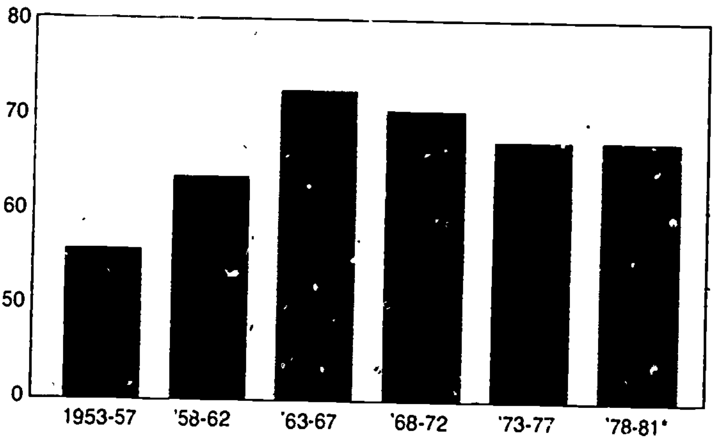
Industry's Share of Academic R&D Support Has Declined From 1950's

PERCENT OF TOTAL UNIVERSITY R&D FUNDING FROM INDUSTRY



Federal Government's Share of Academic R&D Support Has Fallen More Recently

PERCENT OF TOTAL UNIVERSITY R&D FUNDING FROM FEDERAL GOVERNMENT



*Estimate

Note: Data exclude R&D performed at federal R&D centers administered by universities

Source: Adapted from Kiefer *Chemical & Engineering News*, December 8, 1980 Original Source National Science Foundation try/university relations in science and technology have been characterized as curious mixtures of respect and condescension, and some approaches to industry by university personnel have overtures of "with your money and our brains. . . ." If such attitudes exist, it is most unfortunate. I believe that, for many reasons, we should be encouraging closer relations between industry and universities. Although mutual feelings of reservation and perhaps even distrust probably exist, there likewise are areas where relationships are excellent. In dozens of contacts with industry and other segments of the private sector during my tenure as a research scientist in nutritional physiology at Iowa State University, I can recall not a single bad experience. Iowa State researchers in agronomy, animal science, veterinary medicine, and many other biological areas have experienced a rapport with the private sector that is similar to mine. Often the funding is continuous for many years.

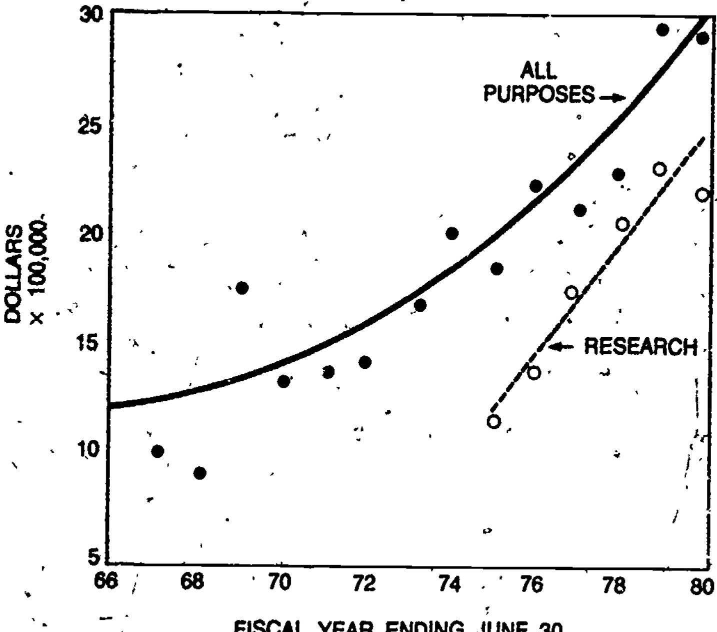
One case was recently brought to my attention by Professor Walter Fehr of the Agronomy Department at Iowa State. For the last 37 years the hail insurance industry has provided funds annually to support research directed toward the development of procedures to estimate accurately the effects of various degrees of hail damage of soybeans on subsequent yields. There are many examples of funding of a specific research project for five or ten years or more. Another part of Fehr's program deserves mention: Since 1972, the Iowa Soybean Promotion Board has provided funds annually in support of the soybean breeding program at Iowa State. This support makes possible the maintenance of plots in Puerto Rico where four crops of soybeans can be grown per year, thus increasing the rate of improvement which Fehr is able to attain. The funds of the Soybean Promotion Board are derived from soybean producers (farmers).

Another example of long-term funding from the private sector is that provided annually, since 1973, by the Iowa Beef Industry Council in support of research in the Department of Animal Science on the effect of type and amount of dietary fat and protein on blood and tissue cholesterol and on lipoproteins. Here, too, as with the Soybean Promotion Board, the funds of the Council are of producer (farmer) origin.

Industrial grants constitute about 6.0 percent of the research budget at Iowa State University. During the past five years, total research expenditures (exclusive of the Ames Laboratory, U.S. Department of Energy) have increased from $22 million in 1974-75 to $37.8 million in 1979-80. Over the same period, funds made available for research from gifts, contracts, and grants from businesses, corporations, foundations, and associations increased from $1.15 million to $2.3 million (Figure 2). The proportion of total research funds from the latter increased from 5.2 percent in 1974-75 to 5.9 percent in 1979-80 with slightly higher percentages in the intervening years.

FIGURE 2

Gifts, Contracts & Grants From Businesses, Corporations, Foundations and Associations to Iowa State University



There are, however, substantial differences among colleges and areas within the University. Funds from business and industry to the College of Engineering in FY 1979-80 were approximately 9.0 percent of the total research budget. In the College of Veterinary Medicine the proportion from industry in 1978-79 was 6.0 percent. In the Agriculture and Home Economics Experiment Station the "trust and special" component, which largely involves funding of research by the private sector (such as industry and commodity groups), was about 13 percent of the total in both 1974-75 and 1979-80: this represents an impressive increase over the 6.0 percent in 1964-65. The proportions of funds of industry origin channeled through the Agriculture and Home Economics Experiment Station for the Departments of Agronomy and Animal Science currently are about 16.0 percent and 7.0 percent, respectively. Some research units within these departments have higher proportions from industry (20 percent or more). I do not think such a high level of support from the private sector compromises the research program if—

1. Support is accepted only for ongoing or planned research programs (to fund research which we want to do when funds are available), and

2. The relationship is detailed in a Memorandum of Understanding or similar agreement which outlines patent and publication rights.

Such industry/university cooperation provides for a healthy interchange of information between the two communities. Moreover, it strengthens ongoing programs in universities and sometimes releases other funds ("hard" money) for more basic studies. Often the industry support assists young staff members, and established personnel as well, in accelerating and upgrading their programs by providing funds for research assistantships, technical assistance, supplies and equipment. In many cases industry funds provide for greater continuity of support, perhaps not more than state appropriations, but more than can be expected from many federal sources. Usually, too, data evolve that are most useful to industry. In no sense should this industry support be viewed as "charity." Rather, it is an investment in the advancement of science for the betterment of the general public.

Although there are differences of opinion on how best to promote better linkages between industry and university scientists, there is strong feeling in many quarters that such improved liaison is a desirable goal for the future. In some areas the course already has been set, sometimes 20 or 30 years ago; in others. there is still a search for direction and a means of catalysis.

Industry / Academia Interaction in Polymer Science and Engineering at IBM

Dr J Economy Manager
Polymer Research
IBM Research Laboratory

First, le me thank Jim Seferis for inviting me to participate in this symposium. Actually, I have to apologize, since my experience in the area of industry/university interfaces is really limited to the last three or four years. However, in that short span of time we have put forth some rather vigorous university programs of a relatively exploratory nature. It's these types of programs I want to discuss with you, and I'd also like to get some feedback in the form of your views as to how we're addressing the industry/university interface.

I'd like to start, though, by picking up on the theme that Paul Tebo introduced, namely, the theme that polymers is a mature field as opposed to the view I hold that polymers is, in fact, a very exciting, vibrant discipline.

There are a number of concerns facing the field of polymer science Thus, in the past decade only one new polymer was introduced to the marketplace. You might contrast this to the 1950s, when a number of new polymers were developed. The question that emerges is whether this is a result of the maturity of the field of polymer science and engineering, a view to which many people subscribe, or whether is there a real opportunity to develop new polymers. There is certainly a real need for new polymers, particularly in the electronics industry, where the need exists for more sophisticated materials that do not exist today. Unfortunately, in the past decade the polymer industry has tended to look to research programs with shorter term payoffs, and for good reason. Thus, governmental controls, OPEC, the uncertainty of the economy, and the larger increasing capital investments required for bringing aboard a new product—all of these have acted to dissuade management from the pursuit of new materials, and they have tended to adopt a more defensive posture. One concern that I would raise is that after a decade of these policies, many companies that once were skilled in innovation and in bringing new products to the marketplace no longer possess these skills. In fact, a new kind of research management structure geared to more conservative goals is set in place, and it would be hard to dislodge that kind of a group, even if we ever were to come back to the point where we wanted to develop new kinds of polymers. Another problem with presently available materials is that they are not really adequately characterized. Another concern that I would like to raise is that there's a lot of variation in the materials that we purchase, and many of the major producers really no longer have the skills to adequately characterize the materials.

Finally, with respect to the programs in the universities, it's probably not apparent to the uninitiated, but most of the polymer activities are really concentrated in only three or four departments. They're good departments, but the fact of the matter is that chemistry departments throughout the university system typically ignore or avoid getting involved with polymer materials even though perhaps half of the graduates from chemistry departments become polymer scientists. I would also point out that there is very little work being conducted on the synthesis of new polymers in the polymer departments. This is a traditional posture assumed by academia because historically industry always maintained a very strong synthetic effort. But today, now that this is no longer the case, it's important that the universities begin to examine that position a little bit more carefully. I also am concerned with the quality of the students. The fact of the matter is that most polymer departments are part of a graduate school and have no direct ties to undergraduate departments. Hence, they aren't able to attract the best students.

Now let's look at the positive side—why polymers represent a very important and exciting field with great potential for growth. It should be noted that many new polymer properties have been identified only within the past decade. For example, take the issue of stiffness. Only in the past decade have we learned how to prepare polymers that have the stiffness of steel. With respect to temperature of use, we've only recently been able to demonstrate that polymers can be used at cryogenic temperatures. With respect to electricals, certain polymers now are being shown to be conductive while copolymers of polyvinylidene fluoride have been shown to have very high dielectric constants. Both properties may be of considerable importance to the electronics industry. With respect to surface characteristics, recently we've observed that certain classes of polymers are not only very good lubricants, but also can be designed to display very good adhesive characteristics. Not to belabor the point, it's clear that the potential to develop and combine these various features in polymers is as exciting as ever, and the opportunities are as great as ever. Probably the fact that these are not commodity materials but rather are specialty polymers may inhibit some organizations from considering these materials more seriously. Continuing, one can further tailor the properties of polymers by the control of molecular weight, crystallinity, tacticity, and selection of comonomers. These are techniques that one can use to further control polymer properties. On the other hand they represent structural features that one must have very sophisticated skills and techniques to control. Keeping all these variables under control is part of the reason that most of the polymers available today are really not quite acceptable for highly exacting applications.

Turning now to some of the programs that we are carrying out with universities, we actually have a number of programs that are funded from our department. First of all we provide fellowships that are designed to help those schools that are just beginning to establish polymer programs. We have different types of programs with the three major polymer departments; namely, industrial sponsors, an unrestricted grant, and an instrumentation grant that was designed for a new, young faculty. Perhaps the most interesting university interface is the one we designate "directed research." It's designed to support a professor in an area that's relevant to our interests and to carry out basic research in that area in a collaborative vein with one of our own professionals. For example, the scientist in a university may be working on the synthesis of a new material, and his counterpart in our laboratory would be concerned with the characterization of the material. Currently, we have several such programs planned for 1981, and others are being negotiated. From our present point of view, this appears to be a very promising technique to develop an academic/industrial interface.

It's noteworthy that we also maintain a sabbatical program for university people. For example, in 1980 five professors were on sabbatical in our department for anywhere from one month to one year. More recently we've also started an internal sabbatical program where people from divisions of the company will come and spend a year or longer working with us. This is a very important program, since this interaction provides us with an insight into the more applied needs of the company as well as long-range technical directions. Continuing, we now have a fairly active postdoctoral program, which includes both domestic and foreign postdoctorates. These programs basically are designed to encourage our scientists to carry on basic research in relevant areas to produce publishable work. Some of the other programs that we have under way include summer students, summer faculty (NSF program) and supplemental students. I might return to the first point; namely, the sabbaticals for the professors. Having a professor spend a few months to a year in our laboratory can provide a real impetus to subsequent "directed research" efforts.

Finally, I would like to touch on some of the issues that I think are critical to this kind of a meeting. With respect to patents, there is a serious problem in terms of the reality versus the expectations. My experiences are that very few patents are really important, and patent issues tend to cloud negotiations between industry and universities. Hence, we try to define our research programs with university people so that they really won't lead to inventions, but rather will provide a broad base of scientific knowledge in that particular area. A second point of concern is in maintaining the proprietary nature of the work. As noted earlier, a number of non-IBM scientists are in our laboratories and are exposed to all of the polymer work. Perhaps the fortunate thing for us is the fact that the strategic value of this information is not obvious since it is really applicable to the design of chips and the design of packages. I think in the coming years polymer scientists will become more sophisticated in these areas and then this may become a problem. With respect to the issue of publishing, at worst, there only should be a one-year delay; and at best, typically, we publish almost immediately the kinds of work that emerge from the activities of the postdocs or the professors. The one-year delay, of course, is a delay that's encountered in applying for a patent and then submitting for the foreign equivalents. The foreign equivalents are usually published within a matter of days.

Industry / Academia Interaction in Polymer Science and Engineering at Case Western Reserve University

Dr J Lando Chairman
Department of Macromolecular Science
Case Western Reserve University

Today I'm going to talk about the joint industry academia programs that the Department of Macromolecular Science at Case Western Reserve University has been involved in over the past seventeen years and also to point out the directions in which we intend to go in the future. Before I can really do this, it is necessary to describe the Department of Macromolecular Science briefly, and as I do I will point out places in which we have had academic industrial interaction. Then I will summarize the interactions that we have and point out those we wish to develop in the future.

Table I describes the personnel in the Department. The figures in parentheses give the expected picture for the immediate future: the figures without parentheses are the numbers at present Thus we have 13 full-time faculty members. These are faculty members who have their appointments in the Department of Macromolecular Science; nine are associated faculty with primary appointments in other depart-

TABLE I

Department of Macromolecular Science Technical Personnel

Faculty	13+9	(17+10)
Research Associates	15	(25)
Graduate Students	68	(75)
Undergraduate Majors	42	(60)

ments It should be noted that we are a true academic department with postdoctoral, graduate and undergraduate programs. The unusual undergraduate program leads to an engineering degree with a polymer science major. The previous speaker is correct in stating that a major problem for polymer graduate programs is getting good graduate students. If other universities develop undergraduate programs as well, this will aid in solving this problem. We have 68 graduate students listed here and expect to have 75 this fall. We have about 20 research associates at the present time, and we actually have 16 faculty members, 3 of whom will be joining us in the summer of 1981. Thus, we have a relatively large graduate department with a relatively small undergraduate program.

Table II concerns our undergraduate degree program, which is strongly interfaced with industry. I should mention something about Item 3 in Table II because it relates to our interaction with industry We encourage our undergraduate

TABLE II

Undergraduate Program

UNIQUENESS

1 Accredited degree program in polymer science

2 New Society of Plastics Engineers chapter organized by undergraduates

3 Unusual research experience for undergraduates

4 Balance between science and engineering

NEW PROJECTS

Newpher Laboratory for Polymer Processing students to join the research group of faculty members as soon as they elect this program, usually at the end of their freshman year. Because of our large graduate program and small undergraduate program, we are able to treat our undergraduates almost like graduate students. We encourage them, if they wish, to get involved in research programs. We make an issue out of getting an industrial job for each major during the summer between their junior and senior years. One of the problems in setting up a program of this kind is that at the outset the faculty, with only one member a trained engineer, was heavily biased towards the sciences. Thus, we were very conscious that we had to have a balance between science and engineering, and we used our industrial contacts to ensure that the design of the program was an appropriate one. We do have an adjunct professor from industry who helps us teach polymer engineering and processing. Two of our new faculty appointments are engineering oriented. The Newpher laboratory for polymer processing, stressing polymer composite processing, is now being built. It is an educational advantage for our undergraduates to have such a laboratory, and it also provides research opportunities. C. Richard Newpher is a graduate of Case Institute of Technology and is a leader in the composite processing industry. He and his people are helping us to design and to equip this facility. Another point I would like to stress is that the undergraduate program itself derived from suggestions from our industrial sponsors program that I'll discuss later.

The graduate program is described in Table III. A distinct aid to the development of our graduate program has been our Industrial Sponsors Program, which has provided seed money for new projects and facilities, such as those listed in Table III.

The research thrust areas of the department are listed in Table IV. Let me say that the central research theme of our Department has always been characterization. Other areas have grown from that base. Structure-property relations and composite materials are major thrust areas of our Materials Research Laboratory, and these areas have generated some industrial support to the MRL, although not on the same scale that Dr. Roy was talking about. Our industry-supported composite materials research supplements the work that is being done at the University of Delaware, because we have been interested primarily in the characterization of the fiber-matrix interface. The last three items in Table III also have grown out of the central strength of our Department. We are interested in the design and synthesis of polymers for specific, end-use applications and are consequently interspersed in things such as electrical properties, unusual mechanical properties, or potential use in prosthetic devices.

TABLE III

UNIQUENESS

1 One of a few major graduate programs in macromolecules

2 Success of our graduates in industry and academia since birth of department

3 Major Instrumental Facilities for characterization of macromolecules

NEW PROJECTS

Newpher Laboratory for Polymer Processing

Central Computer for computer operation of all major instruments

The three major industrial interactions are listed in Table V. First, I would like to discuss our cooperative program in undergraduate education. It is a voluntary Case Institute program that is in its formative stages. For those students who do not elect this program, we intend to maintain our policy of obtaining for them summer positions in industry between their junior and senior years. It should be noted that some of our graduate students, just after obtaining their Master's degrees, but before embarking on their Ph.D. programs, spend a summer in industry.

Table VI contains the major industry/academic interac-

TABLE IV

Research Thrust Areas

1 Structure-property relations

2 Composite materials

2 Synthesis and characterization of unique new materials

4 Biological macromolecules and biomaterials

5 Novel processing and characterization techniques

TABLE V

Industrial Programs

1 Cooperative program for undergraduate education

2 Industrial sponsors

3 Major research projects with industry

tions in the Department's Industrial Sponsors program. A number of these items are similar to points mentioned in the much broader Institute-wide MIT Industrial Affiliates program.

Our Industrial Sponsors Symposia, the first item, are held twice yearly. Our graduate students and research associates give talks on their research at these two-day meetings. Thus, our sponsors see our people technically and socially a year or two before they graduate. In addition, the students learn from the pressure of having to give research talks in a formal setting.

Short courses for industrial sponsors have been given on a number of subjects, including composite materials, vibrational spectroscopy, and mechanical properties If we don't have the expertise in a given area, we bring in people from the outside The third item in Table VI relates to formal information exchange. In the past, several copies of every paper that we published were sent to each of the sponsors. As the Department grew, this became prohibitively expensive. Now we do the next-best thing. When papers are going to be submitted to a journal, we put aside the abstract, make up a booklet, and send these booklets to our Industrial Sponsors every few months. Thus, these companies have prior knowledge of everything that we publish.

TABLE VI

Industrial Sponsors Program
The Interactions

1 Industrial sponsors symposia

2 Short courses for industrial sponsors

3 Inf rmation exchange

4 Industrial sabbaticals

5 Input into programs and directions of the department

6 Discretionary funding to department

7 Additional interactions

The industrial sabbatical program has been limited in numbers but highly successful. Industrial scientists have spent six months to a year working on any project they choose with any professor, have sat in on any course they wanted to, and then have gone back to their companies. We have had about five or six examples over the past fifteen years. The typical industrial person that does this is someone who has been in management for ten years and wants to update his research skills. These people have been relatively happy with their experiences. There also has been a successful example of a faculty member spending four to five months in an industrial laboratory. We feel this program should be expanded.

The Industrial Sponsors have had considerable input into the programs of the Department. We don't take all of their advice, but such advice is carefully considered. A formal meeting is held between the industrial committee of the Department and representatives of the sponsoring companies twice a year for the purposes of explaining goals and of soliciting advice. This takes place the first evening of each Industrial Sponsors Symposium. Two suggestions that we have successfully pursued have been the idea that we get into the composite area and the suggestion that we develop an undergraduate degree program. What I am trying to emphasize is that the discretionary money that comes to us as part of this program is not the only benefit we receive from these companies. The input that we get is also very valuable.

Discretionary funding from the program is primarily used for matching funds for equipment, seed money for new faculty members, and for seeding new projects.

Additional interactions are encouraged and usually are developed on a one-to-one basis with a sponsoring company. These include courses conducted by members of the faculty at the company and jointly supported summer research programs at Case for both high school students and undergraduates.

Finally, in addition to the above program, we are planning to expand our direct research involvement with industry. We now have a grant from the National Science Foundation for the planning of an industrial/academic research institute. Our major problem here is to design an institute that does not interfere with or damage our Industrial Sponsors program. We also are encouraging the expansion of individual research projects with industry that are related to the mutual interests of the parties.

I hope I've given you an idea about the industrial interactions that we have at the Department of Macromolecular Science at Case and what we plan for the future. Thank you very much.

Industry / Academia Interaction in Materials Science and Engineering at Rockwell International

Dr P Cannon Vice President
Research Center
Rockwell International

Rockwell International Corporation is a seven billion dollar, diversified manufacturing company. We build aircraft; we build space vehicles, nuclear reactors, electronics for defense, electronics for commercial purposes; we're the world's largest independent supplier of bits and pieces for heavy-duty trucks, and we build industrial machinery. We're a highly decentralized set of rather independent divisions.

We have a broad range of interactions in all our businesses with universities, including all the things you've heard about—we have people on leave at universities, people on leave from universities with us, liaison programs, exchanges, and adjunct professorships, to mention a few. But this afternoon I want to deal with one particular topic, one particular set of relationships that we've developed very extensively, and that is the direct contracting of research between industries and universities. We can deal with it two ways; we are actually a contractor to some universities, but the principal topic, of course, is our subcontracting of work to universities in the area of so-called directed research.

Two things need to be talked about: the *how* and the *why* of our industry/university interactions. The *how* I'll describe by example; the *why* Rockwell gets involved as .tensively with universities as it does needs some background. Rockwell has tens of thousands of subcontractors, and the corporate research laboratory is no exception. Corporate funding for the research laboratory constitutes about one-third of the total revenue that has to be taken in to ensure the programs; two-thirds comes from elsewhere, from private and government sponsorship. When we take contracts, we find it very appropriate to be partnered with universities.

The *how* of these interactions can be summarized in a story. It is not unlike the situation that obtains when you go out with your child or your nephew or grandchild to buy them a toy for a present. You can't buy a complete toy these days; you have to buy a toy in a kit form, and they're all extremely complicated. When you take it back to the store and complain, all you will get is, "That is a toy to educate a child for today's world. Any way you have put it together is wrong." Now, there is no single solution, no single answer to how you put together a relationship between a university and an industry. Any way you do it will probably be wrong for somebody else, and it is very important to recognize each relationship as a separate experience.

There's a temptation to seek out new and expensive programs, a temptation perhaps reinforced by activist social philosophies at the national administration level, rather than to work at adjusting existing policies that may have become ineffective or maybe even counterproductive. Someone at this workshop may address that issue, but I need to spend my time on what's really successful under the forces of the marketplace. I consider that I work for an employer operating in a market-driven economy (under public regulation), with substantial public procurement of our offering of goods and services. This latter procurement is responsive to the collective, expressed needs of many people, but it does tend to be slower than a transaction in a free market between individuals. I mention this because it means we can't turn our contract efforts on and off quickly—and neither should universities.

What then are the market functions of our respective institutions, if we're going to deal with how they should interact? The primary societal function performed by universities, I believe, is education; and nothing should be allowed to interfere with that. In some schools this includes, and in fact is dominated by, the training of technical professionals, technical vocationals, and managers. There is a strong sense of particular mission. Nonetheless, those schools are "universities," and such "training for work" is education and should not be subordinated to other activities.

The whole process of education has, however, become extremely expensive, partly because of the breadth of coverage that's required. Science has grown from a single area of natural philosophy in 1850 to 5 branches recognized in 1900, to 26 in 1942, and I understand the National Science Foundation has now recognized over 500 separate branches of science and engineering. I submit that there is no one institution in the educational world that can afford to maintain excellence in all these areas, and we need to recognize the consequent importance of specialization and choice in the educational market function.

This is not, however, a plea for exclusive and early specialization. Please understand that in business we still need to see undergraduate students trained in classical skills, training that provides them with discipline of the mind together with the social, literary, and language skills appropriate for the 21st century. I think it's quite a shock to realize that we're training young Americans today who can't speak Spanish, can't speak German or French, let alone Russian or Chinese; for those of us who live on the West Coast and look across the Pacific basin at the coming 21st century, that's especially hard to take. We also must sustain breadth of education for living as well, so the graduate school is probably where we should concentrate on teaching and maintaining the expensive topical specialties to which industry and public research money can be expected to pass on a contract basis.

I want to emphasize that I do believe we're talking about symptoms of a very simple and common problem. It's not the only problem that we face, but here we should deal in simple propositions. What we're really talking about is the front-end funding, to the tune of about $500,000,000 a year, of American technical, graduate-level education. At this workshop we're all struggling with the search for that front-end money. it is not necessarily all discretionary. Where is it to be found? $500,000,000 is a great deal of money, however, appropriately divided by, say, 500 (for example, the Fortune 500) it becomes a distinctly manageable problem. In

Rockwell, we share the maximum amount of our contract re-search that we can with appropriate, competent people and institutions in the world of the universities. We place substantial funds into these subcontracts, and some of the money flows to graduate education, and with it flows the vitality of industrial endeavor.

Money, however, is only one factor for universities and industry to resolve. Together we also must meet the peak industrial demand for scientists and engineers. Many of us don't believe it's appropriate to build a human plant in each company, everywhere maintained at the level of peak demand any more than you in the universities believe you should build your physical plant to the level at which the peak annual demand could be accommodated. An appropriate vehicle for training, and a way to smooth the demand peaks and valleys may be a direct, continuous coupling of universities and industrial research laboratories. Industrial research laboratories in the context of this talk will be those labs that are "captive" to a business (let's not forget those businesses themselves may be endangered today by diversions of funds to regulatory compliance issues, and may not be able to do everything they'd like to).

The current congressionally legislated solution for coupling individual labs and universities (e.g., generic centers of technology proposed under the Stevenson-Wydler bill) may also be a diversion of useful resources from the search for educational funding. Many of us, of course, don't feel the need for prior federal endorsement of specific industry/university linkages. We've had a number of such linkages of our own, which we started by ourselves with significant money committed on our own initiative. Of course, we attempt to draw public funds to those programs whenever we think it appropriate and when funds become accessible. And we've been able to persuade the National Science Foundation and others that such was the right thing to do.

Two of the "direct coupled" programs that we started contributed not only to technical needs, but also to the societal needs normally met by universities. We became deeply concerned about a shortage of trained people and, particularly, with the losses from the working population associated with the under-representation of minorities in science and engineering, especially at advanced-degree levels. Let's remind ourselves that Black people constitute 11 percent of the American population, but the percentage of Ph.D.-holders represented by Black people is barely ½ of 1 percent. In 1976 the Rockwell Science Center, first with corporate funds, then with NASA and subsequent DOE support, started a three-year program with Howard University and North Carolina A&T to establish a strong technological research base at those two schools in the field of solid-state electronics. We transferred some highly proprietary gallium arsenide solar cell technology, and we provided the resources and expertise to build the related labs. Thus, we established a base that has made those schools self-sufficient today in obtaining research contracts in this important field. We now continue in what we regard as a more normal contractor-subcontractor relationship with the two schools. The catalytic phase is behind us.

In another similar program, Rockwell assisted in the establishment of New Mexico State University's nondestructive evaluation training program. Today's advances in manufacturing techniques, the expanding requirement for reliability, and especially in complex assemblies like nuclear plants, automobiles and aircraft, place a great demand on the early economic detection of flaws or defects. Some of you probably spotted the story about the liquefied petroleum gas tankers that were laid up, not because the steel in the tanks fractured, not because the hulls fractured, but because the plastic insulation that was foamed in place had voids in it, and there was no way to get it out short of stripping those ships all the way down to the keel. The absence of an on-line technique for the detection of flaws in foamed plastic has led to a direct loss of about $300,000,000 in laid-up shipping, and a consequent reduction in the capacity of the industry to ship liquefied natural gas from Algeria to Texas and Massachusetts. We need more people to develop and apply nondestructive evaluation techniques, and our nationally recognized program with NMSU has provided access to education and career opportunities for a number of people in southern New Mexico. This and the gallium arsenide program are just two of the university/industry programs that we've started, without prior government approval, on the basis of our own perception of our own needs.

We also have a number of joint programs that are pointed at very specific technical goals. A recent one is an NSF-funded joint program to define the thermodynamic parameters of fracture in ceramics, joint with the University of Florida; and to those of you who are a little bit concerned about the semantics of basic versus applied research and industry versus university involvment, I submit to you that is a basic program of substantial industrial importance.

Our next speaker, Rustum Roy, and I are two members of a triple partnership between Penn State, Rockwell Science Center, and Rockwell Energy Systems Group on the ceramic containment of defense radioactive nuclear waste. The three organizations are mutually bound by contract (not by grant) to perform certain tasks and deliver certain items, data, and specimens of contained material. Naturally, the deliverables are an industrial responsibility, while the studies of long-term stability are being led by Rusty and his team at Penn State.

I emphasize the word *contract* deliberately because it is the key to the relationships that exist in the use of directed research funds in a university setting. Sometimes a contract—a binding arrangement—is a foreign idea to college folks, who might prefer to be completely free to get on with some new and exciting idea. (We sometimes feel that way in industry. We were brought up the same way people in universities were brought up, to feel that that which is new is always exciting; but we do have to finish the contracted items first, or our clients get mad. They won't come back with the next lot of money.)

Now for some of the *why's* of our industry/university interactions And, clearly, one of the most important of the *why's* involves the supply of high-level human resources.

Two neglected critical human resource capabilities we think are needed are, first, to ensure that people who are going into nontechnical work—the general public of the United States—have some kind of grounding in science and technology, and second, that those who are going to become professional scientists and technologists have some idea of business, business law, constitutional law, business management, and accounting. That way we'll wind up both competent scientist-administrators and, very importantly, scientist-legislators. They're the ones who will ultimately steer the public decision on where United States technology goes. They're not only the general public, they're the future managers of business, and they're also, very importantly, the properly informed future legislators.

On the broader need for people, a little food for thought is in order It's recently been stated that (given the demographics of the United States and the birthrates of ten years ago) even if the present number of jobs in the United States does not significantly change between now and the end of the decade, because a larger number of folks are going to retire in this period. we will have full employment, true full employment, by 1990. The number of people available to work in 1990 will equal the number of jobs that are available today. It's quite a thought, but there are some very serious questions about mix of skills and responsibility for training people who have not yet entered the job market. If we don't manage the mix problem, we'll have a very serious shortage of people for certain classes of work. That's why we believe the recent NSF-Department of Education study is wrong and has overestimated the availability of trained people in the years ahead.

At Rockwell, for example, we could easily be short 5,000 engineers in this decade. That number arises from the fact that many of our aerospace engineers will be at retirement age within ten years. Rockwell employs about 14,000 engineers and scientists. Incidently, we do about a billion and a half dollars worth of research, development, testing, and engineering each year; about $150 million of this is company initiated. It costs about $100,000 a year to maintain a person in a professional Rockwell setting. By proportion, if we are looking for 5,000 engineering and technology people—the source for which we do not yet know—we also expect that we'll need 500 research-grade people. And we believe we're not the only company in that position.

There were comments this morning that demand for, say, 70 research-grade people wipes out the entire supply in one disiplinary field in the United States. Summed up over the aero, electronics, machinery and computer industries, this adds up to a national shortage, which we have extrapolated to a worst case shortage, of about 100,000 fully trained people. We don't believe there's any way in which the existing university establishment will be able to respond to that in the context of present programs.

Demographics apart, whether those people are in universities or not, that's where we in industry have to look for them. We'll be looking to hire, to train, to rent—but not to hire your faculty away; we'll not do that. Indeed, the idea of "renting" people would mean that you could retain your research faculty in order to continue to train the production engineers and the technical vocational people that we need as well as to renew themselves. It may well become the norm to see industrial employment of graduate students on university campuses within ten years, possibly within five years. That may be a solution to a problem that we've all been sidestepping. We have to acknowledge that it is very expensive to go to graduate school. It is a large direct expense as well as an enormous opportunity cost. Let us face it, some of the kids say, "Hey, if I'm going to do that, I can get the same intellectual experience *without the degree* if I go into industry." But we can do both for the student if we can find a way of giving academic credit for work done in an industrial setting by people who are enrolled as graduate students and paid by industry.

Another why of industry/university relationships is quite clear. Our primary interactions with universities are predicated on the contribution that a school can make to our research mission. One of those contributions is fundamental research. In the materials cycle—from extraction, processing, and fabrication, to operating life and ultimately to recycling of expensive, scarce, energy-intensive material in a variety of structures—we see the necessary work as a continuum, a continuum from basic, or roughly what is called basic, applied, or generic work, all the way through to manufacturing.

Sometimes we have to start all the way back at the fundamental structure of materials. We in Rockwell have been very happy in the last four years to have had a good deal of success with a modification of aluminum that we call "Superaluminum."™ This superplastic aluminum can be "blown up" like plastic in a mold to make complicated parts, with a very good reduction of weight and a very large saving in the number of parts that have to be put together to make a final structure. We think we see a way to do the same thing not only with titanium, in which the phenomenon is well recognized, but also with nickle-based alloys and possibly with ferrous-based alloys. We could be on the verge of changing the metal fabrication trades, and that will be quite a change considering the fixed investment that exists. The old adage of what is your basic research is my applied research, because you're in a university and I'm in an industry, is particularly true in the materials cycle. And that, I think, is why we've talked so much about it this afternoon.

In closing, I'd like to re-emphasize that I think it's the *how's* of the industry/university relationships that have to be carefully considered; they're all individual. Our obligation in industry is to our stakeholders. That may be a word that some of you haven't heard too often; it includes stockholders, employees who have an interest in continuity, customers who have an interest in quality products and services, and all those who might be affected by the products and services that industry puts out. Industry's goals are to deliver efficiently, profitably, and responsibly those products and services for its stakeholders. If university people can help us

do that, then we want the closest kind of relationship wi'
you.

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University / Industry Coupling: Philosophical Underpinnings and Empirical Learnings

Dr R Roy Director
Materials Research Laboratory
Pennsylvania State University

The current interest in university/industry coupling is long overdue. Regrettably, the interest has some of the character of a fad in the press, some of the tenor of a media hype on the part of agencies looking for justifications for budgets, and a little bit of the taste of desperation on the part of universities looking for any new source of research funding. If these are the obvious wrong reasons for encouraging much more intensive university/industry coupling, what are the proper reasons? These are of two kinds. I will address the questions of educational philosophy first.

In any situation where interest is suddenly fanned, it is wise to ask: Has anybody studied the literature or track record? The record in this case is abysmal. From recent writing on this topic it might appear to the novice that the concept of university/industry coupling was discovered de novo in about 1978. The same two or three rather recent examples (such as the MIT-Exxon, Harvard-Monsanto, MIT-Polymer Processing, North Carolina-Furniture) are treated in detail as though they were the only specimens in captivity of industry and universities interacting; meanwhile, nationwide, industry-wide examples with histories of decades are ignored. I can in this short article neither critique exhaustively the recent literature, nor perform the exhaustive studies to document systematically the long track record. In its place I will offer an updated conceptual framework[1] that will attempt to systematize the interactions which actually do occur between these two major performers of research. I will, in addition, provide anecdotal references illustrative of various generic types of coupling in order to provide those interested with a fuller picture of the total enterprise.

A Philosophy for University-Industry Coupling

In the 1920s and 1930s university science consisted of dedicated teachers who possessed the "amateur's" dedication to research. A significant part of the research was very much a common venture by industry and local universities to build a new industrial base. The government as supporter or buyer of research didn't exist. Agricultural research, always closely coupled to its industry, was a significant exception. It is said that in 1930 the U.S. Navy refused to hire a second chemist because it had one! But this benign governmental neglect all ended with the war.

The next social contract, written about 1950, between science and its patron, society, is in its turn now crumbling. After the war the government's reward to the fledgling science establishment for producing "the bomb" was much more than money: it was trust, and hope almost elevated to soteriological dimensions. By 1980 a number of false expectations and values built up by the public, government agencies, etc., aided and abetted by the research community in academia and in some government-financed industries, had been exposed. I list only the four major errors:

1. More money for basic researc' (always undefined) leads to technological and economic health. *The decline in the U.S. economy has come to a nation of Nobelists. The Japanese, specializing in applied science, seem to have done rather well.*

2. We can have centers of scientific excellence in every country by putting more money into the system. *Clearly, excellence is limited by people and to "critical-mass" assemblies of them.*

3. "Basic research" (done mainly at universities) is higher on the pecking order of science than applied research; hence, we should put our best people into that. *This is the most egregious error of them all.*

4. Reallocation of basic research budgets among scientific disciplines is to be carried out under the PGR (perverted Golden Rule) which states that "Them that has the gold makes the Rules." *This obviously militates against new*

fields of science, the very ones that are tied to the innovations being made in industry. The neglect of p[illegible]er science and engineering by chemistry departments is a glaring example of the studied indifference of academia to societal realities. Big science (particle physics, astronomy, for example) budgets remain sacrosanct, while new fields or new seeds such as the overlap of the major research systems of universities and industries receive token amounts to deflect criticism.

During the 30 years since Vannevar Bush's manifesto, "Science, the Endless Frontier,"[2] science as savior has changed to the spectre of science as destroyer of the environment and possibly of the race. Science is seen, accurately, as problem-creator, and at best as an "ambivalent" human activity best described by C.F. von Weizsacker.[3] In the eighties it is certain that decision-making about science will no longer remain the province of the scientists alone. Even the fundamental epistemological paradigm of the isolation of the system for study is in question. Some assert that to do good science, to ask the most *important* questions, it is necessary now to ask about its relevance to the larger system of knowledge and its use. The total system of science is now known to be strongly internally interactive. The interactions are in two dimensions. The first interaction is along the continuum of the disciplines arbitrarily divided and labeled physics, chemistry, biology, etc. The second dimension is more relevant here. Orthogonal to the first is the continuum from fundamental (or the most abstract) science to applied science, to engineering, to development.

The philosophical bases for university/industry interaction in research are five-fold:

1. It will catalyze the crossing of the artificial boundaries separating the so-called disciplines and will avoid the destructive narrowing forced on students by the departmental structures of universities. (For a detailed development of this theme, see reference 4.)

2. The vast majority of university research groups are simply *incapable* of making really fundamental or *basic* re-

search contributions any longer. They are subcritical in size and in quality, most of them by an order of magnitude. The exceptions amount to no more than two dozen in any field.

3. While university research must be funded both to produce well-educated and well-trained graduate scientists and to keep faculty intellectually alive, the research can be vastly more effectively used at the level of applied science connected to industry, and the education will be better for the broadening.

4. The selection of problems to be studied, which is now determined by the individual and an anonymous, hopelessly bureaucratic selection by so-called peers, must become much more closely attuned to the needs of society via both the change in orientation of the faculty member and the research goals themselves.

5. University research not only will be more useful, it will be better because it can become more interactive (with "local" industry) in both dimensions, and because each institution can draw on the other's limited intellectual and physical resources.

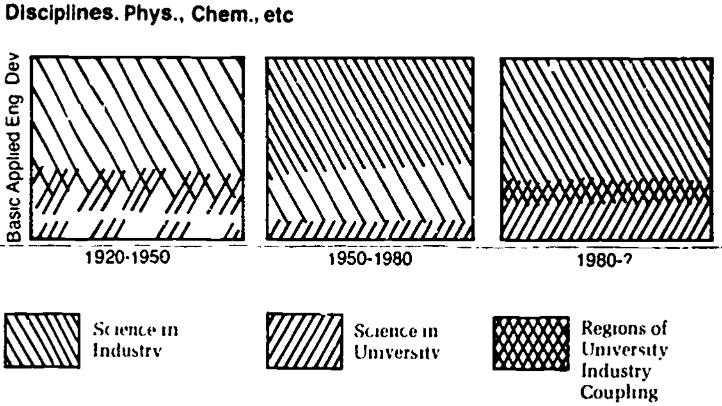
Some Neglected History of University/Industry Coupling

We have already noted the extensive contact between industry and universities that occurred (albeit at a miniscule dollar level) between, say, chemistry and metallurgy departments and their respective industries in the 1930s. Consulting was an important part of this, and it helped shape the intellectual orientation of the faculty. The land-grant tradition initiated by the Morrill Act brought considerable contact between the two groups, in "agriculture and the mechanic arts."

However, the part of the record most neglected by writers who themselves were not involved in these matters (e.g., reference 5) is the record of two institutions: the DOD and the Industry Associations. The Department of Defense, since the late fifties, had developed a system of program management that attempted to assemble the best possible teams of industry and university research groups to work on DOD's broad problems. These clusters often were managed by a prime contractor with strong DOD input. They all achieved a genuine scientific interaction in both dimensions of Figure 1. The dollar scale of such programs, which continue to this day at a high level in DARPA, dwarfs all the new programs of other agencies. These efforts were typically multidisciplinary rather than interdisciplinary (see my detailed definition in reference 4) with integration of results done in group meetings of the team and by the manager.

A second set of major actors in coupling was the innumerable industry associations such as the American Petroleum Institute, the American Iron and Steel Institute, the Lead-Zinc Institute, etc. Here, industry funds went to support "telestic" (i.e., purposive, end-oriented) basic research at universities. The amounts involved in individual grants

FIGURE 1



A sketch illustrating the changing patterns of research emphasis in U.S. science in industry (shaded NW → SE) and university (shaded SW → NE). In the pre-war phase the isolated pockets of basic research in universities were overshadowed by substantial overlapping research with industry in selected areas (e.g., chemistry but not in physics). During 1950-1980 overlapping applied science was neglected at universities in favor of discipline-limited basic science. The emerging trend, in a zero-sum research budget change, may well be much [illegible] emphasis on applied science, with less discipline rigidity, and with a [illegible] zone of overlap with industry's own re-emphasized capacity for longer term research.

were very substantial (for those days), and some API projects, for example, lasted for 10-15 years. In many ways this was an ideal model of universities doing basic telestic research that was judged by the potential users in industry to be of sufficient value to them that they paid for it. The absolute magnitude of actual support *of research* at universities by industry is also not well documented. We have not a single survey of the secular variance of the actual dollar industry support, discipline by discipline, received by a spectrum of universities for the period 1950-1980. I suspect that the magnitude will be as large as some of the present newer initiatives.

A Framework for Systematic Discussion of U/I Coupling

In my paper of 1971[1] I provided the first attempt at separating out the very different kinds of interaction in research that occur between universities and industries. The reader is referred to this paper for details. Failure to make elementary distinctions between very different activities confuses the literature in this field. In Table I, I show an updated and more differentiated version of the categorization, in the form of a matrix. One axis contains the different objectives of the interaction (and the source of funds), the other the different mechanisms used within the university to achieve the objectives.

The table is essentially self-explanatory; examples entered in the various boxes help to explain each. The vertical axis is particularly significant, in that it identifies the institutional structures needed in a university. The single grant (A) to a single faculty member, of course, requires no change. The "Industrial Associate" type of program discussed at length at this meeting (B) is not, in my considered opinion, a viable mode for any but a handful of the biggest research universities. On the other hand, the creation of (C), stable, societal-need-oriented, interdisciplinary laboratories (for air pollution, transportation, water resources, etc.) is a *sine qua non* for universities serious about coupling to industries. These laboratories automatically provide an ongoing structure that

TABLE 1

The Infrastructure of University-Industry Coupling

$ FROM →	INDUSTRY				GOVERNMENT State		Federal
		Research Projects			Research Projects		
OBJECTIVES → / UNIVERSITY MECHANISMS ↓	MANPOWER DEVELOPMENT AND IMPROVEMENT PRESTIGE CONSULTING	DRIVEN BY UNIVERSITY'S IDEA	DRIVEN BY INDUSTRY'S NEED	LONGER TERM COLLECTIVE SUPPORT	JOB-CREATING RETAINING	COUPLING OF NATIONAL SKILLS	DITTO ON CONTINUING BASIS
A. Single Grant or Contract at University	Fellowships, Advisory Boards	Very large number. Small percent of total support of universities during 1950-80		Quite common API, AISI, "Pb-Zn" etc.	PSEF, NY, Conn., etc.	DoD DoE NSF IV	
B. Cluster of grants/contracts with university (and ? industry)	← Industry-Associates or affiliated program →					DoD NASA (NSF-Engg)	
C. Designated Interdisciplinary Experiment Station or Center with U/I as one objective		Large number of university-wide interdisciplinary laboratories or Exp. Station on Materials, Environment, Transportation, etc. Only a few receiving much industrial support			← Both sources →	NSF-Center program	ARPA, DoD-JSEP NSF-MRL's, etc.
D. Stand alongside Center							USDA, USGS, Commerce, new Gen. Tech. Centers
	I-1	I-2	I-3	I-4	G-1	G-2	G-3

not only can serve the public sector, but also can serve as the proper multidisciplinary, quick response mechanism to couple to industry. The traditional "Experiment Station" at land grant universities was a good model. The Georgia Tech revival of this tradition is an outstanding example.

In Table II, I list some of the incentives that are present for both sides in such industry/university collaboration. Also listed are the preconditions for success in this area. These are based on our local experience (described below) with some thirty years of continuous coupling in the field of materials research at Penn State. My observations are that not all universities are conditioned by *attitude* and *tradition* to such coupling. Overstimulation by the government of U/I

TABLE II

Incentives

FOR UNIVERSITIES	FOR INDUSTRY
• Some of best science is interactive (with society's needs) and interdisciplinary	• U.S. Innovation position demands NEW ways to use *finite* pool of creative persons
• Best preparation for graduate students (w.r.t. attitudes, problem orientation)	• Utilizes newest ideas and developments based on $4B public-funded research
• Widens range of access to sophisticated equipment	• Access to nationally outstanding personnel and facilities *in some areas*

PRE-CONDITIONS (Only for the SELECT Set)

Faculty and facilities in area must be: (a) First rate for modest companies (b) Outstanding for largest companies	• $-Decision maker who believes in it
• Intellectual (not $) *desire* by faculty must provide motivation	• Bench scientist who wants it
• University *structure* to encourage, protect, maybe reward	• Easy and frequent (constant) communication (telephone, visits, *personnel on site at university*)

coupling will result in a host of unqualified beginners, often trying to achieve coupling under pressure, and in a high percentage of casualties. Even given a favorable institutional climate, successful coupling only can be based on the especial strengths of the faculty and facilities in specific areas. Furthermore, even desire and excellence on the part of the faculty can sustain a good program for only a decade or two. Unless the university institutionalizes by structure changes and rewards a base for such coupling, even the most successful experiments will disappear. For a long-term change in university patterns, *all* the following conditions must be met: an area of especial strength (equipment, ideas, experience) with a group of faculty, a favorable attitudinal climate on campus, and institutional commitment.

In Table III, I present the alternative *funding* mechanisms that have been proposed or tried so far to enhance U/I coupling. It will be noticed immediately that the role of government as *catalyst* is a new concept, but the widespread support for the idea in recent months augurs well for the future. The present funding systems have two very different styles of achieving coupling. The first is the classical DOD model of finding the very best people and putting them to work jointly on a task (i.e., it is the *manager's* responsibility to find the best people).

The other approach (used by NSF) is to invite individuals, pairs, and groups to "propose" under a variety of rubrics and to have such proposals reviewed, etc. This tedious, time-consuming system is particularly ill-suited for effective coupling. The parameters required for successful coupling are much too subtle to be described and evaluated by competitive peers. Very often the industry may not want even to show the direction of its thinking by its choice of basic problems, etc.

On the other hand, the ideas newly emerging from the Commerce Department studies,[6] and Vanik Bill,[7] etc., essentially have the government *stimulating* the coupling by rewarding *performance*. It should be noted that the public accountability is much superior ' re, since it is post facto. The grant is not made to the company, nor to the specific project, hence it is not a gift to the company. The matching grant is to the institution to help it do more of the same in any way it chooses.

Simple administrative edicts, such as requiring agencies to have a minimum of their research in joint contracts and providing "Independent Research and Development" funds to universities under the new A-21 guidelines to be used in such U/I programs, would immediately launch a nationwide coupling program by the institutions that so wished.

TABLE III

Alternative Mechanisms for Government Investment in U/I

GOVERNMENT AS "CATALYST"

INDUSTRY SPENDING ITS OWN MONEY IS A MUCH BETTER, DIVERSIFIED AND EXPERT "REVIEW" MECHANISM	• **Stimulate U/I—via tax incentive to I (*Baruch*[6]; *Vanik*[7])** • **Stimulate direct I → U research support by providing matching support (from 1:1 → 3:1) directly to individual or 'department' (not university) (*Baruch*)** • **Stimulate by requiring all federal agencies to have "X" % of budget in joint U/I work (*new*)** • **Add on IR&D (Independent Research and Development) surcharge on government contracts to universities as part of A-21 to couple to I**

GOVERNMENT AS ACTIVE PARTNER OR INTERMEDIARY

- **Agency manager coordinates interactive research involving 2-8 U/I labs. Widely used by DOD for 25 years.**
- **Proposals by U and I separately for joint research (present NSF mechanism)***
- **Proposals by U + consortia of I for seed grant or on-going program (present NSF program)**

*Considering the amounts involved, this mechanism is probably a NET LOSS to U.S. science and innovation. Total U/I man years in meetings + proposals + review exceeds the modest funds committed to the program so far.

The advantages and disadvantages of the two systems are summarized in Table IV. I believe that the science community is much too passive in a democracy: it needs to express its preferences among the options listed above, to congressmen and agency heads.

A Case-Study: Materials Research at Penn State

Using the categorization developed in Table I, Table V summarizes historically only a sample of different kinds of coupling that have occurred over the last three decades in

TABLE IV

Feedback to the Feds!
on Basic Pattern of I/U Funding

CHOICE "A": PERFORMANCE-BASED INCENTIVES

For every dollar which industry gives to university for research (not gifts) FEATURES: Saves precious faculty time. Saves precious industry time. 'Peer' review is by competent site visit + $ investment Patents	N.S.F., "N.T.F.," or Commerce will: • Provide (X for 1) matching to university-department-individual (not to grant alone) • Possible tax write-off for industry

CHOICE "B": PROPOSAL-BASED PROMISES

Two proposals prepared and "reviewed" (often by amateurs in the technology with no knowledge of industry and no investment in the outcome).

- Enormously costly in scientist time.
- Best industries will not participate in cutting edge areas.
- Proprietary issues complicated.

TABLE V

Penn State—Industry Coupling (Post War)
in Materials Science and Engineering

NATURE OF COUPLING			
	Metallurgy Co-op	~20-30 companies	1946-present
I-1	Ceramics and SSS "Fellowships"	~10-20 companies	
	MRL Industrial Coupling Program	~10 companies	1962-present
I-2	Hundreds of "projects"	30 companies	1946-present
	(a) Bethlehem Steel	slag research	25 years continuous
I-2	Industry association support	Se-Te; Pb-Zn API AISI Glass Science Inc.	1-3 years each 10 years 10-20 years 3 years (dissolved by anti-trust)
G-1	*GSAC-MAP (state)	6 universities 10 companies	13 years
	**R.I.S.C., etc.	10 companies	6 years
G-2	NSF Hard-materials	5 universities 20 companies	4 years
G-3	very large number, e.g.		
	• DOD bomber wing coating	3 universities 3 companies	4 years
	• DOE radwaste	Rockwell-PSU Westinghouse-PSU	1978-
	• DOD transducers	3 separate contracts	1976-

*Governor's Science Advisory Committee, Materials Advisory Panel
**Resident Industrial Scholar program to "re-tread" industrial personnel
#See Table 1

the departmental and interdisciplinary structure at Penn State.

Manpower-producing and -improving activities have always been well supported by industry in the form of fellowships, etc. Project support by industry has been continuous, but it has its ups and downs in total volume. Typically, these are one-to-three-year projects, but they have a much quicker start-up and much less investment of marketing energy than the "peer-review" system of government. The amounts involved are substantially less than are available from government, but the restrictions are many fewer. The striking example of the continuous support of a research project in a department for 25 years by the Bethlehem Steel Corporation should be noted. Both absolutely fundamental data (on 3+4 component phase equilibria) and invaluable technology in slag management came out of this work. Another relatively rare type of coupling is the G-1 or G-2 type, where the state government, through its Pennsylvania Science and Engineering Foundation, vigorously advocated and supported such coupled research. Some outstanding successful examples (e.g., with Erie Technological Products on the high voltage capacitor) emerged from this kind of coupling.

Recently, coupled research paid for by the government has assumed a major position in the laboratory's budget, amounting to over 25 percent of the total.

But obviously, getting research funds is only a small part of the story. The real difference is the land-grant tradition of doing the very best science for "Agriculture and the Mechanic Arts." The Materials Research Laboratory, for example. started an Industrial Coupling Program from the date of its creation in 1962. It operated the Materials Advisory Panel—a consortium of 10 industrial and 6 university research leaders, for 16 years. In 1972 the laboratory held what was possibly the first national meeting on the topic "UniversityIndustry Research Cooperation, The Record and The Promise." It has been a vigorous advocate for and practitioner of coupling for 20 years.

Our coupling also extends to innovation in *training* within

100

industry and at universities through the Educational Modules for Materials Science and Engineering project, which provides new materials as vehicles for training.

The laboratory is perceived by industry as an institution dedicated not only to conducting basic, published research, but to directing its efforts in tandem towards solving societal problems. Patents have never been any problem within our coupling efforts, and the development of university innovations by corporate structures has been possible with no difficulty and with equitable division of any benefits.

Conclusions

I have attempted to provide a fuller overview of the national efforts in U/I coupling, past and present. A philosophical basis for encouraging U/I has been developed on the basis of the absolute need for reversing the reductionism of much modern science. A categorization of the wide variety of objectives and response mechanisms enables one to compare, meaningfully, different U/I programs. A look at alternative mechanisms for government intervention in the U/I process shows the enormous advantage of the matching grant, post facto, performance-based approach.

Finally, I have described briefly, as a case study, some of the activities in coupling at Penn State in the materials science and engineering field.

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Master's Degree Program in Computer Science Under Contract to a Large Electronics Firm

Dr. W. H. Matchett, Dean
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New Mexico State University

Introduction

At New Mexico State University we have made several attempts to provide graduate instruction in a manner that will meet the needs of nontraditional student groups. For example, we are in our fourth year of delivery of a field-based Master's degree program for in-service teachers. The program is conducted almost entirely on location. The only on-campus requirement for enrolled students is their final examination, which is administered by a committee of resident graduate faculty. This program is partially funded by the state of New Mexico. We present a classical program, under contract to the Air Force, in electrical engineering to students at a nearby Air Force base. Essentially, the same program is delivered to employees of an electronics firm in Juarez, Mexico. This program is presented, in part, in the Spanish language. We operate an electric utility management program that is funded in large part by contributions obtained from a consortium of privately owned utility companies in the western United States. This program is conducted on the main campus in Las Cruces and draws students from the traditional group as well as from the nontraditional or mid-career group. In all these efforts, we have maintained a very traditional stance and have attempted to deliver programs in an entirely conventional manner with the same quality and rigor as in our on-campus, traditional degree programs.

The Program

The program described in some detail here is one in the area of computer science, which we offer under contract to a very large electronics firm. This program enrolls approximately 35 employees of the company selected from among a very large number of engineers from all over the United

States. Selected employees apply to the Graduate School and are screened in the routine manner. Those who are accepted are regularly admitted as graduate students in the program. They spend a 5-week period of residence on the campus of the University during each of 5 consecutive summers. They are housed in residence halls and are accommodated in almost the same way that traditional undergraduate and graduate students are housed during the regular school year. During this 5-week period two, 3-credit courses are presented. Students attending the program for 5 successive summers may thus expect to earn the 30 credits required for completion of the program and receipt of the Master of Science Degree in Computer Science.

The course offerings which comprise the program are as follows:

Summer 1980

CS 479 Special Topics Immigration Course (laboratory) — 3 cr.

An immigration course providing the needed foundation for the NMSU program. Included will be an intense introduction to topics from computer system architecture (CS 205,-366), programming principles (CS 321), and discrete mathematics (Math 330). Prerequisite: working knowledge of one machine or assembly language, and one higher-level language.

CS 467 Simulation Concepts and Languages 1 — 3 cr.

GPSS, SIMSCRIPT, and other languages as they relate to discrete simulation in decision making. Their application to inventory, scheduling, queuing, job shop, and gaming. Prerequisite: elementary calculus and statistics and working knowledge of one higher-level language.

Summer 1981

CS 471 Programming Language Structure 1 (laboratory) — 3 cr.

Syntactic and semantic features of prominent programming languages, and their effects on language applications. Prerequisite: CS 479.

CS 472 Data Structures (laboratory) 3 cr.

Study and analysis of algorithms for sorting, searching, and storage management; influence of data-structure selection on clarity and efficiency of algorithms. Prerequisite: CS 479.

Summer 1982

CS 463 Architectural Concepts 1 3 cr.

Relationships between the micro and macro levels of computer architectures, and between architectural and computational structures. Prerequisite: CS 479.

CS 579-1 Special Topics in DBMS and MIS 3 cr.

Study of selected topics from the areas of data-base management systems (CS 482) and management information systems (CS 485). Prerequiste: CS 472.

Summer 1983

CS 579-2 Software Development: Design and Management (laboratory) 3 cr.

Study and use of modern and effective techniques for the design and implementation of reliable software, and for the management of software development Prerequisite: CS 471

CS 578 Management Information Systems 2 3 cr.

Use of computers for integrated total management information systems. Emphasis on current experimental systems. Prerequisite: CS 579-1 (summer 1983)

Summer 1984

CS 599 Master's Thesis 6 cr.

We have completed the first summer of operation of the program and are looking forward to the second summer session, which will be convened during the summer of 1981.

Some Interesting Challenges Presented by the Program

Problems that surfaced during the project development period included a question concerning the admission policies and procedures in place in our Graduate School. Company representatives did not fully appreciate the bases and rationales of our requirements for admission and were of the opinion that they should play a more significant role in determining the admission status of their employees. We engaged in very detailed conversations with representatives of the company and, at length, achieved some resolution of this problem. In our enthusiasm to see the program through to a successful beginning, we relaxed our admissions standards somewhat, and, as a result, some of the students who were admitted to the program would probably not have been admitted to the traditional program. This led to problems that arose later on during the session itself. We initially justified these exceptions to our usual standards on the basis of the prior professional experiences of the applicants. It turned out that these prior experiences, while valuable to the development of their careers and their relationships to the company, were not entirely relevant as determinants of success in our Master's program. Indeed, it seemed to the instructional staff of the program that the prior training and backgrounds of some of these students were obsolete or obsolescent.

During the first session it became clear that care must be taken by instructors to be cognizant of the possibility that the class may have an internal structure of its own. It may have first- and second-level managers who in their company assignments might have positions quite senior to those of other students in the class. Such persons might suffer embarrassment as the result of academic deficiencies that might appear in their work in the classroom. Instructors in such programs must be alerted to this possibility and must take steps to avoid difficulties arising from this situation.

Regularly enrolled graduate students in the Department of Computer Science who were not associated with the contract program expressed a certain amount of dissatisfaction with what they regarded as "pampering" of students in the contract program by members of the faculty. For example, the contract included provision for certain amenities for the students like coffee breaks, cocktail hours, bus trips, and other kinds of social interactions with each other and with the faculty. Students in the regular program were not necessarily aware of the provisions of the contract or of the policy of the company. It must be mentioned, in all fairness, that their perceptions had some basis in fact.

Students in the contract program seemed to be confused about who was in charge of the course and of the program. Students were uncertain about the roles of the academic department head, the course instructors, the company training coordination person, the graduate dean's office, the office of the academic dean, and other administrative or service offices on the campus. This pointed up the necessity of explaining very carefully to the contract students the organization of the university and the roles and functions of the several academic, administrative and support offices available.

Faculty and student interaction occurred, but not at the level or to the extent that had been anticipated by the faculty. Faculty involved in this program had assumed that there would be many opportunities for intense interaction on a one-to-one or small-group basis. That this in fact did not occur was perhaps a reflection of the heterogeneous nature of the student group. Some of these students were as good as the very best graduate students we have in the university; others probably should not have been admitted to the program. The contract students registered several complaints about the quality of the dormitory accommodations and the food service that was provided. It very quickly became clear that these students were comparing our dormitory and food service accommodations for undergraduates with accommodations that are available at the company's educational and training facilities. At the company's facility, accommodations would compare very favorably with those available in a first-class hotel. It also became clear in listening to such complaints that the contract students had been conditioned by in-house training programs to expect that any kind of educational experience should be more like a vacation or relaxation period than a continuation of one's work or professional assignment.

Plans for Continuation

We plan to start the admissions process early and to provide much better definition of the criteria for the screening of applicants for admission. We intend to provide both company education coordinators and potential students with a clear statement of the rationale for our criteria and standards concerning admission of students.

We plan to provide "warm-up" sessions on location at the company training center, with the intent that these sessions would provide a catch-up period for newcomers to the program and a refresher course for returning students. One of the instructors in the first summer program will travel to the training center of the company in late May or early June to conduct the "warm-ups." The length of the session will probably not exceed two weeks.

We encountered some problems with the five-week session and are giving very serious consideration to the adoption of a session of six weeks' duration. The nature and the amount of material presented, coupled with the marginal ability of some of the students in the program, suggest proceeding at a somewhat more deliberate pace.

We shall intensify our efforts to inform students about the present state of computer science as a discipline. We shall further intensify our efforts to explain our objectives in presenting the program. Some students raised the question of relevance concerning the theoretical bases for some of the concepts presented, and we plan to introduce these topics in a thorough, and, we hope, more satisfactory way. We plan to use the curricular recommendations of the Association for Computing Machinery and the Institute for Electrical and Electronic Engineers.

We plan to inform students more precisely of what to expect in terms of the quality of dormitory accommodations and the food service that is available. In this way we hope to avoid any surprises.

In view of the heterogeneous nature of the students in the class and, particularly, their varied backgrounds in computer science, we are giving serious consideration to the use of computer based learning modules in the next classes. We hope that these modules will enable instructors to proceed through their courses without undesirable delays or digressions.

Benefits Derived from the Program

We anticipate professional exchanges between our faculty and the professional staff of the company. These exchanges may take the form of teaching of computer science on our campus or at the company training center. We also anticipate opportunities for collaborative research. Although none of these has yet materialized, we see no reason why they should not develop in the near future. We see this program as offering a model for attacking the problem of extreme shortages of technically trained individuals, and we believe that this program will provi ; a paradigm that may find applicability in other industries that are anticipating or experiencing such shortages. We believe that this program has enabled us at New Mexico State University to utilize our facilities and resources more effectively. People and facilities poorly utilized during the summer period are more fully utilized through this program.

Part of the revenues obtained from the program have provided discretionary funds, which have become available to the Department of Computer Science and to the Office of the Graduate School. These funds have supported developmental efforts such as recruiting of graduate students, support of faculty and student travel, and general department needs. Discretionary funds are, of course, extremely important in times such as these, characterized by budgetary constraints on the one hand and the inflationary spiral on the other hand.

Perhaps most importantly, this program has provided an opportunity for our faculty to learn first hand of the actual applications of computer science in industry. The students are learning what the field of computer science encompasses and what they might expect from research and development in the field in the immediate and near-term future. We look forward with anticipation to the continuation of this program and to the successful conclusion of its first phase in the summer of 1984.

Philadelphia Association for Clinical Trials: Review and Prospects

Dr. J. Schrogie, Executive Director
Philadelphia Association for Clinical Trials

Background and History

The concept for the organization now known as the Philadelphia Association for Clinical Trials (PACT) originated in 1978 during discussions of the Philadelphia International City program, which was being fostered by the Greater Philadelphia Partnership, the leading private sector business group in the area. As a part of this overall effort to enhance the economic growth and development of Philadelphia, members of the partnership recognized that the well-developed and respected medical research resources of the Philadelphia area could provide an attractive opportunity for the placement and performance of clinical trials of new drugs and devices.

To examine the matter further, determine its feasibility, and plan its development, a steering committee was established under the chairmanship of Dr. Lewis W. Bluemle, Jr., president of Thomas Jefferson University. Other members of the committee included senior executives of the area's academic teaching institutions and representatives of the local pharmaceutical industry. The committee was encouraged by the results of preliminary surveys of the academic institutions and surrounding pharmaceutical companies which documented both an interest in and need for such an organization. The organization was formally incorporated as the Greater Philadelphia Organization for Clinical Trials (GPOCT), a not-for-profit corporation, on January 3, 1980.

Meanwhile, each of the area's six academic medical teaching institutions formally endorsed participation in PACT by resolution of its board of trustees. After further consideration of administrative and financial requirements, a chairman of the board of directors (Karl H. Beyer, Jr., M.D., Ph.D.), and executive director (John J. Schrogie, M.D.) were selected in April 1980. Subsequently, the office was located within the

University City Science Center, a centrally placed facility in Philadelphia.

In June 1980, the first board of directors meeting took place, at which time the name of the organization was changed to the Philadelphia Association for Clinical Trials (PACT), each of the nine original member institutions nominated a representative to the board of directors, and the appointments of the officers were confirmed. Thus, in a space of less than two years, PACT moved from idea to reality.

Role of Pact

GENERAL GOALS

A major objective of PACT is to facilitate the relationship between the sponsor interested in evaluating the safety and efficacy of a project and the academic clinical research laboratory capable of performing the study; the sponsor's interest may extend also into monitoring the effects of the product in broad use after approval for marketing has been granted. Similarly, PACT desires interaction with various governmental agencies such as the Food and Drug Administration, National Institutes of Health, or Veterans Administration, which conduct large-scale research programs to evaluate presently marketed products or to study the course of various diseases as they may be affected by therapeutic interventions.

PACT IS UNIQUE

As a nonprofit organization developed and endorsed by the six area academic medical institutions, PACT represents a unique collaborative effort by the health-care delivery and research community of the greater Delaware Valley. This support places PACT in a central role to coordinate and exploit several related features of this region:

1. The core of six medical teaching institutions;

2. A group of 40 community hospitals which participate actively in teaching and research programs of the parent institutions;

3. A population base of 5.6 million people;

4. A concentration of major pharmaceutical companies lo-

cated in the immediate area and throughout the northeast quadrant of the country and;

5. Close proximity to the major governmental participants in the development and evaluation of health-care products located in the Washington, D.C., area.

Pact Will Provide Services

ESTABLISHMENT OF INVESTIGATOR INVENTORY

As an initial step to establish the coordinating process, PACT has distributed a questionnaire to survey the clinical research resources in the area. It was sent with the direct assistance of the executive offices of the medical schools to clinical staff members of their institutions and affiliated teaching hospitals. Based on the nearly 400 responses, an inventory of clinical investigators interested in participating in PACT-sponsored activities has been established and will be maintained by PACT. Thus, specific facilities and scientific resources can be conveniently identified and matched with the requirements of potential sponsors. Any apparent gap or change in information will be updated as required.

SUPPORT TO CLINICAL RESEARCH PROGRAMS

In addition to collaborating with already established and recognized research programs, PACT is committed to expanding the base of investigators available to participate in clinical trials. Although it is clear that the number of potential patient participants, medical skills, and technical resources available within the area is extensive, mobilization of these factors into the organization of a clinical trial can be difficult. Such studies usually require a multidisciplinary participation of specialized skills, laboratories, equipment, data management services and selected patient populations that would not be found outside of the largest teaching university institutions.

PACT is in a position to coordinate resources between institutions so as to take advantage of the established skills of each. This function can be performed in a number of ways:

1. Assisting in protocol design and project coordination,

2. Supervising the delivery and inventory of investigational study materials,

3. Providing trained monitoring and surveillance of study progress, and

4. Arranging for data analysis and reporting.

In short, through the skills and participation of its staff, PACT can fill any gaps preventing a productive interaction between sponsor, investigator and patient.

FOCUS FOR EDUCATIONAL PROGRAMS

By virtue of its central position with reference to area medical institutions, PACT will have knowledge of and access to the best qualified scientists available. Thus, it could serve as a clearinghouse for technical consultation requests, could organize training programs and seminars, and could consider the development of a prestigious scientific publication that would be oriented to the research advances being accomplished in this region. It also could act to develop innovative programs to stimulate interest in difficult or neglected areas of drug research such as matters of informed consent or pediatric clinical pharmacology.

Present Activities of PACT

AREAS OF SPECIAL INTEREST

As PACT has developed, its major activities may be classified as—

1. Clinical trials—designs, monitors and analyzes the controlled clinical trials necessary to establish the safety and efficacy of new therapeutic modalities.

2. Postmarketing surveillance (PMS) and epidemiology—plans for identifying cohorts for study as well as placing large populations under long-term observation are under development.

3. Preparation of research proposals—can work with investigators to develop and write applications to supporting agencies.

Important support to PACT's programs is given through the active collaboration of the Data and Information Systems Center (DISC) of the University City Science Center (UCSC).

This convenient and highly experienced unit is well qualified to handle the large volumes of data generated by multiclinic trials. It provides a full spectrum of data coordinating services ranging from assistance in forms design, training and monitoring of data collection staff and procedures to data reduction and statistical analysis.

PROGRAM DEVELOPMENT

Since its inception, PACT has participated in developing a wide variety of projects which reflect the breadth of its mission. A representative sampling of topics includes:

- Assistance to investigators needing statistical analysis of project results
- Placement and monitoring of an antibiotic efficacy trial
- Organizing regional participation on a large-scale vaccine trial
- Submission of a contract application to federal government for clinical and epidemiological study of ophthalmic disease
- Development of a system design and coordination plan for a national PMS study of an antibiotic
- Collaboration with pharmaceutical marketing research groups to enhance the scope of presently existing survey systems
- Feasibility study of regional drug surveillance system
- Submission of a contract application to federal government for study of bioavailability of drug products
- Submission of a contract application to federal government for feasibility of in-hospital drug surveillance

Discussion

The text that follows is a distillation of the discussions inspired by the presentations made at the workshop. A great many questions were asked of the workshop's invited participants, some of which elicited answers or comments capable of contributing to the reader's understanding of the issues or programs discussed during the workshop. A great many other questions, questions often focused so sharply as to provide additional information of value only to the questioner, have been excised from the discussion section that follows. ed.

Comment by Dr. Bruce. Let me just say a few words in general about university/industry cooperation and interaction. I think it's useful to draw some sort of a map, if you will, of these sorts of interactions, and I'd like to make use of a study by New York University's Center for Science and Technology Policy that has tried to categorize the sorts of interactions that universities and industry have. They've come up with two basic categories, and I think a third is needed. First, there are collaborative research mechanisms. Among these are the research consortia that we've talked about briefly this morning. They are the university research projects that are funded by industry; they are government-funded, industry/university consortia. The second category comprises knowledge transfer mechanisms. In this category I would include the liaison programs, continuing education, cooperative programs, consulting, personnel exchange, etc. Finally, I think that there is a third kind of interaction, and that is the whole area of philanthropy. Industry is a great source of unrestricted giving to our nation's universities and colleges, and so I'd talk about those three as a sort of map within which we operate. I'm sure that we would all agree that the lines separating them are not sharp; they're very fuzzy, but we need some sort of structure on which to hang our remarks, because we're going to be jumping from one to the other throughout the day, I expect.

Question addressed to Dr. Baron. *It seems to me that there is a limited number of companies large enough to be altruis-*

tic—to, in other words, provide support money without any focus on short-rate returns. Many of the smaller companies can't afford to provide money without some insurance—some direct results. You consequently have what I guess amounts to an elite group of companies. Can you see any way of defining which companies are capable of joining this elite class?

Dr. Baron. First, I don't think that even we large companies are doing enough. I think industry should do more than what it's doing now. But all of us, big and small, can do something. Small industries can participate by banding together, for instance. A little money from each of many small industries will go a long way. I for one would not like to see such associations do anything more, though, than give money. I would not like to see such an association set up to judge which professor gets funded for which particular project. That, I think, would be a perversion of the intent. But if a small company cannot give enough money even to support one graduate student, surely it could band together with other companies in a small association (and I would hope that it would be a small one, not something that becomes a bureaucracy) to fund one graduate student somewhere. I don't think there's a lower limit to this. There's also no limit to the danger of a burgeoning bureaucracy, so I would suggest that this association be kept small and have no other purpose than to donate.

Question addressed to Dr. Baron. *Despite your comment earlier that relations between industry and academia are just fine, I believe that there is at least one problem of potential seriousness, and that is our seeming inability to communicate with each other on some matters. Let me illustrate what I mean with the example of the field of chemical engineering as we know it today. The field is experiencing a peculiar problem; it cannot rejuvenate itself. I was talking not long ago to one of your recruiters from Shell Development. He is looking for seven Ph.D.s. Du Pont, at the same time, is looking for an additional seven. That takes care of almost one-fifth of this year's supply of eligible Ph.D. chemical en-*

gineers in this country. So there seems to be a breakdown in communication. Somehow the system is not working. If industry successfully competes with academia in hiring these new Ph.D.s, then it limits the ability of the profession to rejuvenate itself. Within the context of the amorphous relationship that you suggest industry and academia effect, how can problems like this one be worked out?

Dr. Baron. You're referring to the problem that there aren't enough Ph.D.-level graduate students in chemical engineering and, as a consequence, you gentlemen are finding it difficult to find faculties. I suspect that a reason for this is the very high salaries currently paid on a Bachelor's level. People of this academic generation (which I believe is sort of a reaction to the sixties' generation) want to go to work and earn their money and are somehow not willing to invest in their intellect. This is a sociological problem that I don't know how to solve. We can't go to the universities. We cannot tell graduate students that it is best to get a Ph.D. Many an executive vice president of Shell Oil Company does not have a Ph.D. Many do, but many others do not. Nor can you say that it is necessary to get an education in order to make money or that a Ph.D. is worth so many dollars. So it's not a money question, it's a sociological question. I have no doubt that du Pont, Shell, Exxon, and other companies who need Ph.D. chemical engineers will find themselves very short; they'll get desperate and raise the starting salaries. I'm sure this will happen. It will happen without delay. And the question is what do you do in the meantime? You, suffer, that's what you do. I think that what we are talking about is the lack of a sufficient intellectual climate in this area, which at the moment baffles me. I don't know why these people don't go on. I know why I did go on. It had nothing to do with hoping to make more money. It was that I was restless and would have felt very unhappy if I didn't know what the frontier of my profession was. That's why I went on. There's no other reason. Apparently, there is now a shortage of these people. The problem is even worse than it appears because many of these graduate students are not American citizens, and these students will leave this country when they have finished their degrees. So my guess is that the total available supply is something like half what the statistics say, so we're producing only something like 20 percent of what we need.

Questions addressed to Dr. Bruce. *I have two questions. First, I don't take Dr. Baron's comments lightly, and I would be very much interested in your reaction to his thoughts. Second, I'm interested in the kinds of authority the liaison officers in the program at MIT have.*

Dr. Bruce. I, too, am very concerned about the fox-chicken syndrome. We make a point of telling our faculty openly that we are in no way forcing them to interact with any of our industrial affiliate members. There are members of our faculty who will have nothing to do with the program, and we say that's fine. That's their decision. There are others, though, who will use the program as a way of exploiting their own research interests by gaining support from industry in fields of choice to them, so I think it can work both ways. Now our officers' access in the companies depends to a large extent on the individual company. We try to make a contact very high in every company that we interact with, typically a research vice president or even the president of the company itself, in many cases. That tends to give us much better ways of connecting that company's interests with the work under way at MIT. There are some companies that we interact with that hold things extremely close to the vest, and we interact with them that way because that's the way they choose to make use of the program. But we also encourage the broader interaction that lets our officers really get to know what's going on in the company and what the company's interests are.

Question addressed to Dr. Bruce. *How much discretion do the MIT liaison officers have in their discussions with industry participants in your program?*

Dr. Bruce. I've never been successful in shutting an MIT faculty member up yet when he had something he wanted to say. We have a very active patent program at MIT, so we try to capture the patentable ideas and devices that come from research. Most of our faculty members are extremely aware of the issues of disclosure and in their conversations will abide by those constraints. They make sure we file the application, etc., before they have conversations that might lead to an improper disclosure. But it's dealt with on an individual faculty member basis, which has both advantages and disadvantages. We try to minimize the bureaucracy.

Question addressed to Dr. Bruce. *Do you have a fee schedule, and if so, do all the member companies get the same services?*

Dr. Bruce. All member companies get the same services. Fees have historically been a problem in the sense that prior to my assuming the directorship of the program some two years ago, there was less of a business atmosphere in the program than there is now. Consequently, our fees range all over the lawn, so to speak. At the present time we quote $30,000 a year for the industrial liaison program. There are some companies who pay more; there are some companies who pay less. Of our 270 member companies, about 60 companies belong to a part of the program that's reserved for smaller companies whose average sales are between $100,000,000 and $10,000,000. These people pay on the basis of a graduate fee scale that begins at $7,500 and goes up to $30,000. I have to admit, however, that inflation is taking its toll on us, and we will shortly be increasing our fee simply because we can't afford to do it for what we are charging.

Question addressed to Dr. Fuller. *Some of us have responsibilities at our universities to provide seed money for new young faculty so that they can get started on research projects. Of course, Dr. Baron's remark this morning appealed to me very much. That is, he believes that we could seek from industry the seed money that would be for research undirected externally, and that would help these people develop the kinds of research programs and peer recognition that could enable them to successfully compete for funding elsewhere—from, say, the federal government. How would your industry feel about, how do you personally feel about, pro-*

viding seed money for young faculty when really no tangible reward is anticipated by the company?

Dr. Fuller. Well, the program that I am responsible for now is not looking for tangible rewards as I've said, and personally I feel that that's one of the best places that we can spend our money. My conversations with some of the universities have indicated the same thing. Some department heads and professors have told me that neither they nor their colleagues need this kind of support. They're established. They can get funding when they need it. These same people often point to new faculty who they think a lot of and suggest that that's where they would like the money to be put. I think that's where we're going to try to find places to put it. We've got to balance that, of course, in order to accomplish the goals of this program. I've got to balance that with something that's going on in one of our labs so that we can get people to talk with each other. That is what I'm having, I think, more trouble finding; I'm having no trouble finding worthy things to support. There are many, many places where the money could productively be put to work, but trying to match that with people in our organization so that we can really set up this cooperative thing is what challenges. But I agree with you that one of the finest places to put the money is with young people (the departments can tell you who these young people are). Incidentally, the money we give is targeted at the discretion of the university more than it is by us picking out the person to whom the funding goes.

Question addressed to Dr. McCullough. *Your focus on the basic aspects of the issues in a sense steers you away from questions of applicability. This places you philosophically in sharp contrast to the MIT program, where professors are really very knowledgeable about disclosure. Would you care to comment on your philosophy versus the MIT philosophy?*

Dr. McCullough. Well, I feel very comfortable with our philosophy; I believe our sponsors feel very comfortable with it, that they feel we are filling a gap, are working in an area that they need work in, and that we're doing it very well. There are occasions in which patentability can come up. In our particular area, this would be more in new characterization methods, tools, or developments. Recently, one of my students filed for a patent on a new technique he has developed for measuring fiber orientation, but that's a little bit different than attempting to get a patent on a new materials system. We'll find that very little of these will be patentable. We're not doing work in polymer synthesis, for example, so we would really not have that kind of problem to worry about. Patents in the area of processing are enormously difficult to pin down; here we serve only in a consulting way, and the faculty does that independently from their role in the center. It's not handled at the center at all. So I think the very nature of our program has moved us away from the patent problem area, and I hope to keep it that way. That is our intent.

Question addressed to Dr. McCullough. *I would like to know whether Delaware has any feedback mechanism to the faculty as MIT does.*

Dr. McCullough. The faculty receive graduate student support and summer support—summer salaries; that's how the faculty receives money awards. Now, again, the support actually does go into their pockets as normal summer support would. At their request, the center provides equipment and supplies to the faculty in addition to their support. Most of the faculty are given budgets, which they frequently overrun. In terms of feedback on their performance, yes, there's a very strong one. Each year the advisory board reviews each report, each presentation and piece of work, and sends its report back. In this way the faculty member gets feedback on how well the industry is responding to the work he's structured. This feedback mechanism is extremely important for students. These presentations we give each year, as well as the reports the students write, give our students a chance to perform in front of colleagues at a professional level much sooner than if they were in a normal program. It certainly helps the students mature, and I consider enhancing student communication skills a vital part of the educational program. The first talk typically is lousy; the third one is very smooth and polished. When our students come out of this program after having given a series of presentations and writing a series of reports, I think they have received an additional enrichment from the program that they might not have received in a normal graduate school experience that required only a single thesis rather than a number of reports and presentations.

Question addressed to Dr. Bruce. *Do you operate computer services instrumentation facilities? If you do, do you have a prorated fee schedule?*

Dr. Bruce. The answer is no We have tried very hard to stay out of the provision of laboratory facilities for our companies, and while some parts of the institute do provide such services, it's done independently from the liaison programs.

Question addressed to Dr. Bruce. *Are representatives of your member organizations consulted on curricular matters, or are they afforded the chance to discuss these matters with members of your faculty?*

Dr. Bruce. Yes, but informally. There are no organized discussions, but many of the people from these companies, after they have gotten to know faculty, will have those informal conversations that are so valuable in the direction of curricular work in one area or another. Let me add one additional comment. MIT has had a long history of visiting committees for each of its academic departments, and many of the people who are involved on the visiting committees are also involved in the liaison programs. They consequently have a very deep understanding of what's going on and use the avenues provided in visiting committees to inject remarks as well.

Question addressed to Dr. Farrington. *It has been my limited observation, perhaps unfair, that one of the weaknesses of schools of veterinary medicine is that there's a lack of basic research. Most of the research they do seems aimed at producing immediate rewards. What is it that industry can do and what attitudes can industry develop that will precipitate a change in this posture toward basic research?*

Dr. Farrington. It is a fundamental problem. Veterinarians traditionally are in the practice of veterinary medicine and are field oriented. However, now that the numbers of veterinary schools are increasing (there were 17 a short time ago and now we have 25), I think that you're going to find a greater inclination among young graduating veterinarians to take a hard look at research first.

Question addressed to Dr. Economy. *What restrictions, if any, do you place on the number of people that study a period of time in your lab, whether from universities or elsewhere, and what are the other restrictions, if any, placed on what they will be exposed to and what kind of reports they can see?*

Dr. Economy. There are several restrictions. For example, annually we'll have two or three meetings to which the non-regular employees will not be invited. These are meetings where the progress of the laboratory is summarized, and where a lot of personnel issues are discussed. There are also confidential reports that they will not see, typically the kinds of reports that discuss strategic issues. It's almost as though you had two hats—one when you're dealing with the more basic issues, and the talk there revolves around publishing the work, another when you're dealing with internal issues. Periods of interaction vary. We'll have some postdocs stay for a couple of years; professors typically come on sabbaticals from a month to a year.

Question addressed to Dr. Economy. *What kinds of financial arrangements do you have for professors who visit on sabbatical?*

Dr. Economy. All kinds. Some we support fully; some come with half of their salaries paid for; others come fully funded. We're flexible because we have to be. I'd like to comment on that just a little bit. Almost everyone who joins us seems to be different, and it's almost a full-time job, sometimes, handling the contracts and arrangements. A lot of the specifics are dictated by how they prefer to be paid. Does he prefer to continue on his own payroll and have the company, say, provide a grant to the university, or does he prefer to be placed on our payroll as a consultant? There are a number of different plans and arrangements that can be made.

Question addressed to Dr. Lando. *Your program is one of the more intense models in terms of unified, objective goals, contrasting with the MIT model that might be more applicable across the entire university. How do you feel the interaction between industry and the department affects your objectives and goals; and how do you lead industry, and how does industry lead you?*

Dr. Lando. Well, I think that it very much enhances our ability to conduct basic research. It also helps us financially, but as I said earlier, this is not the whole story. We are very interested in the input, but we're also very interested in interaction and in educating our students. For a variety of reasons the fundamental developments in polymer chemistry hadn't been progressing at the rate that people had hoped for. Some of the fundamental questions in polymer chemistry were not being answered. I got the impression of government interference; for example, some of the regulations might have inhibited industrial development.

Question addressed to Dr. Lando. *Do you feel that fundamental research is being strengthened and enhanced by industrial relationships, or is your intention as a department directed more toward immediate problems?*

Dr. Lando. It's only helped because it provides mechanisms for growth. We can bring in new faculty and scientists to interact with us as well as attract good graduate students. I don't think that one can really show any major restrictive influence of the industrial sponsor program on research, only positive.

Question addressed to Dr. Lando. *Do you give graduate credit, academic credit, for the graduate students who are out on cooperative assignments?*

Dr. Lando. Only under some circumstances. In general, however, we have arranged for the student to go to a company to learn. Some projects students get involved in within the companies can be very technologically sophisticated. In general, however, companies look to the university for a complementary relationship, for reinforcement and the desire for the university to do basic research. I don't think this always holds true for other industries that do not have a sophisticated attitude toward research. We're very fortunate in our area to have highly sophisticated research going on in industry to back us up. A requirement, I believe, for academic/industrial interaction is a certain sophistication on the part of the leaders.