New Alliances and Partnerships in American Science and Engineering (1986)

Academy Industry Program;
Government-University-Industry Research Roundtable

Pages
144

Size
8.5 x 10

ISBN
0309321360

New Alliances and Partnerships in American Science and Engineering

ACADEMY INDUSTRY PROGRAM

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

National Academy Press Washington, D.C. 1986

The Government-University-Industry Research Roundtable

The Government-University-Industry Research Roundtable is sponsored by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. The Research Roundtable was created in 1984 to provide a forum where scientists, engineers, administrators, and policymakers from government, university, and industry can come together on an ongoing basis to explore ways to improve the productivity of the nation's research enterprise. The object is to try to understand issues, to inject imaginative thought into the system, and to provide a setting or discussion and the seeking of common ground. The Roundtable does not make recommendations, nor offer specific advice. It does develop options and bring all interested parties together. The uniqueness of the Roundtable is in the breadth of its membership and in the continuity with which it can address issues.

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Publications are available from:

Government-University-Industry Research Roundtable
National Academy of Sciences (JH 308)
2101 Constitution Avenue NW
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Printed in the United States of America

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PREFACE

The Government-University-Industry Research Roundtable operates under the auspices of the National Academies of Sciences and of Engineering, and the Institute of Medicine, as an alternative approach to addressing important issues in American science and engineering. The Roundtable is unique in two respects. First, it was created on the assumption that all sectors--government, university, and industry--share the responsibility for the stewardship of the scientific and engineering enterprise and for ensuring its continuing contributions to the national well-being. The Roundtable Council, which includes senior federal R&D officials, senior officials from academia and industry, and working scientists, and which is the organization's guiding body, illustrates this commitment.

The second unique feature of the Roundtable is its ongoing nature. It is not a group convened to study an issue, write a report, disband, and go home. The Roundtable is a means for addressing the important issues within a structure that provides for continuity and follow-up. To the best of my knowledge, this is the first time that all the parties have sat down together in an organized manner, and on a continuing basis, to examine the critical problems and opportunities facing American science and engineering.

The Research Roundtable is organized into four working groups. Working Group One focuses on the development, identification, recruitment, and retention of talent for science and engineering research. Working Group Two addresses federal-university sponsored research relationships and the physical infrastructure and organizational arrangements for academic research. Working Group Three is concerned with the new alliances among universities, industry, the financial community, and federal and state governments. Working Group Four addresses major issues underlying the entire research and engineering enterprise.

Roundtable Working Group Three planned, organized, and conducted the activities on "New Alliances and Partnerships in American Science and Engineering" on which this report is based. "New Alliances" refer to the joint ventures and cooperative relationships between universities and small and large companies, the financial community, and state and federal governments. As partnerships mature, establish course, and evolve, the nation and all the individuals and organizations involved will benefit from an ongoing capability for monitoring, analyzing, raising issues, and providing a forum for sharing and discussing what is being learned. The Research Roundtable was created precisely to provide such a capability.

The Roundtable approaches this task on the assumptions that (1) the programs and their sponsors, and government, industry, and university policymakers all want to know how well the new alliances are working; (2) it will be beneficial to exchange information and ideas about the criteria to be used in judging program effectiveness; and (3) an ongoing examination of these alliances is necessary if the participants are to be responsive to the issues and observations that emerge as current programs mature and new programs are initiated. The Roundtable sees itself as a facilitator to help the involved parties examine the operation and evaluation of their own programs and to contribute to a framework for ongoing local-, regional-, and national-level discussions.

In its project on "New Alliances," the Working Group has sought to move the discussion from a focus on general models, procedures, and policy issues to an examination of the impacts and effectiveness of the programs. Areas of interest have been the impacts on knowledge and technology transfer between universities and industry, on graduate education and research, on industrial science and engineering, and on the operation and structures of the cooperating institutions. The culmination of the initial phase of study was a conference on December 5, 1985, for exchange of ideas among 200 representatives from governemnt, university, and industry.

The conference was based on an examination of the nature and operation of twenty-one different types of partnerships and on discussions with individuals involved in a number of these programs. Descriptions of these alliances have been included in the Appendix to this report. Information and observations from this investigation were incorporated into a working paper for the conference by Dorothy Nelkin, Professor in the Program on Science, Technology, and Society at Cornell University and Richard Nelson, Professor of Economics at Yale University. The paper provides the basis for Part I of this report.

A number of topics of interest came out of the discussion at the conference and have been incorporated into Part II of this report. There are a few items of particular importance that I would like to highlight.

1) Universities exist to educate people, and one role of graduate education in science and engineering is to teach people to solve difficult, novel problems. This approach produces not only the best

people, but also the best research--particularly basic research. However, there are problems with this system. Since World War II, academic scientists have tended to have strong loyalties to the university. That loyalty is being shared in more recent times with outside institutions. The role of the faculty member and his or her allegience to the university is something that we must pay attention to as these partnerships evolve.

2) Risk-taking is extremely important in research; payoffs from high-risk research tend to be more frequent and faster. The alliances provide an environment for risk-taking activities that may be particularly important in light of constraints on the ability of industry to take research risks on its own. Therefore, risk-taking research in these alliances should be promoted and protected.

3) Competitiveness is currently all-important in our society. Conversations about where science is going in this country, and which fields and programs will receive support, all start with international competitiveness--spelled with capital letters. How we approach competitiveness colors everything in university-industry alliances. The productivity of the research enterprise is one of the central elements of the portfolio of requirements for maintaining the international competitiveness of the U.S.

4) The problem of excessive deficits raises the questions: How are we all going to survive? Is it in the national interest, as far as research is concerned, to continue as we have up until now? Whatever priorities we establish must be responsibly long-term--they must go way beyond the FY 1987 budget crunch. In this period of budgetary stress, we have to mobilize all our resources. We must find ways to get the best science in our universities into productive and effective use as quickly as possible. The alliances between universities and industry may help bring this about. We must be creative in our thinking; we must consider risk-taking. To acheive maximum productivity of the research enterprise, representatives of all three sectors--government, university, and industry--are required to identify the problems and opportunities and to lay out strategies for addressing them.

5) The boundaries between basic and applied research are blurring; advances in fundamental knowledge are becoming relevant to technology development in the near-term; R&D is dependent on and, in some cases, limited by sophisticated and expensive instrumentation; product life

cycles are becoming shorter. Within this environment, maintaining research capacity at the frontiers of knowledge and maintaining technological capacity at the frontiers of product and process innovation require greater collaboration and interaction between academic and industrial scientists and engineers than has been the norm.

One of the important things we learned at the conference is that these arrangements are remarkably diverse. We are looking for new approaches to industry-university collaborations that will maximize their effectiveness and that successfully address the bothersome issues. I invite all interested parties who have new ideas for facilitating interaction among the sectors to send their proposals to me at the Roundtable. We will compile the submitted novel approaches and disseminate them to the broader community. For its part, Working Group Three is now embarking on an examination of state government science and technology programs. Please call my office if you would like further information.

* * *

The success of the conference is due to the contributions of all parties involved. Roundtable Working Group Three, under the chairmanship of Howard Schneiderman, Senior Vice President for Research and Development at the Monsanto Company, organized the affair; under the leadership of Professors Dorothy Nelkin and Richard Nelson, the Working Group prepared valuable background materials; officials from each of twenty-one alliances used for case studies were helpful in providing information about and insight into their partnerships; and the informed comments of the panelists, discussants, and audience provided for provocative discussion at the conference. All these efforts are greatly appreciated. Special thanks go to the Academy Industry Program for co-sponsoring the event, and to the Sloan and Mellon Foundations, the National Research Council Fund, and the Monsanto Company for their generous support for Research Roundtable activities.

Dale R. Corson
Chairman
June 1986

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INTRODUCTION

The last decade has seen a significant increase in industrial funding of university research and in the number and variety of arrangements that involve collaboration between universities and industry. Industrial funds going to colleges and universities to support R&D rose from $84 million in 1973 to $194 million in 1979, and further to $370 million in 1983. It is difficult conceptually as well as empirically to devise a "count" of particular university-industry cooperative arrangements in place. Quantitative assessment of the range of different kinds of arrangements is equally problematic. And it is important to put corporate funding in perspective; the total is still under 5 percent of total university R&D. However, virtually all knowledgeable people who have commented on the matter, have remarked on a virtual explosion over the past several years in the number and variety of university-industry alliances.

The Government-University-Industry Research Roundtable is specially interested in these developments. There is a need to know more about what has been happening, quantitatively and qualitatively. It is important to better understand what lies behind this rash of new arrangements, and the motivations and expectations at work in universities and in industry. As experience accumulates, it will be valuable to monitor what kinds of expectations have been met, and what kinds thwarted; what kinds of programs have worked well, and what kinds have not; what are the problems that have arisen, and how have these been dealt with; and how can one begin to define the public interest in these kinds of happenings and to discern what kinds of policy departures seem appropriate to further mold or constrain them.

Working toward some answers, the Roundtable has initiated an organized inquiry under the auspices of its Working Group Three on New Alliances and Partnerships. The initial phase of the inquiry has been carried out under the direction of Richard Nelson, Yale University, a member of the Working Group, and Dorothy Nelkin, Cornell University, a consultant to the Group.

This initial phase involved, first, a review of historical materials as well as more contemporary analyses and commentaries bearing on the subject. Second, the inquiry included an examination of published materials bearing on 21 contemporary partnership programs and employed interviews and discussions with individuals involved in a number of these. Third, Professors Nelkin and Nelson prepared a paper incorporating information and observations from steps one and two. Finally, with the paper as a starting point, the Roundtable convened a conference on December 5, 1985, of 200 representatives from government, universities, and industry to examine and discuss the issues raised in this inquiry.

The Roundtable approaches this inquiry on the assumptions that (1) the programs, their sponsors, and government, industry, and university policymakers all want to know how well the new alliances are working; (2) it will be beneficial to exchange information and ideas about the criteria to be used in judging program effectiveness; and (3) an ongoing examination of these alliances is necessary if the participants are going to be responsive to the issues and observations that emerge as current programs mature and new programs are initiated. The Roundtable sees itself, not as a detached group of analysts to collect data and issue a report, but as a facilitator of a cooperative effort to examine program impacts. Roundtable activities are intended to help the involved parties examine the operation and evaluation of their own programs and to contribute to a framework for ongoing local-, regional-, and national-level discussions.

This document is a report on the initial phase of investigation. Part I, "Historical Precedent and The Current Context," is taken from the background paper by Dorothy Nelkin and Richard Nelson. In Part II, "Discussion of the Issues," the central issues raised during the conference on December 5 are summarized. Additional commentary on some of the issues by members of the Roundtable Working Group Three is included in Part II; it is set off from the rest of the text by italics. Part III is a brief commentary on the inquiry written by Nelkin and Nelson. The Appendices include the Conference Agenda, the descriptions of 21 university-industry programs that formed the basis of the inquiry, and the list of conference participants.

PART I

HISTORICAL PRECEDENT AND THE CURRENT CONTEXT[1]

The Historical Context

Commentators on recent industry-university relationships sometimes write as if these are new and novel and in some sense stain the otherwise pure fabric of academic science and teaching.[2] In fact, many of the recent programs have recognizable antecedents that go back in time. Many fields of science have traditionally been strongly applications-oriented, and teaching in these fields has for the most part been preparation for industrial careers.[3] Also, many universities have traditionally seen the fostering of local or state industry as one of their missions. This is not meant to minimize the potential for tension and conflict in industry-university relationships. While they have long been an intrinsic part of the academic enterprise, the present situation certainly involves a dramatic expansion in their number and an important change in their character. Whether these constitute fundamental changes in the participating institutions is a matter of dispute and one of the concerns of this inquiry.

The constellation of research universities in the United States arose from several different sources. The group of east coast universities whose grounding predates the American revolution, were originally designed to educate American ministers and other members of the intellectual elite.

Many writers on "university culture" seem to have these institutions in mind. But the American university scene is marked also, and perhaps more prominently, by another group of universities which were formed for quite different purposes. We refer here to the land grant universities, put into place to train common citizens in the agricultural and mechanical arts. Still another strain of research universities, particularly prominent in the current context, grew up as "technical schools," and are

[1]Taken from a paper, "University-Industry Alliances," prepared by Dorothy Nelkin and Richard Nelson, with help by Casey Kiernan, for the Government-University-Industry Research Roundtable. The authors of that paper acknowledge the fount of useful information about university-industry cooperative arrangements contained in a study put out by New York University's Center for Science and Technology Policy. See University-Industry Research Relationships, National Science Board, 1982.

[2]Irwin Stark, "The University Goes to Market, "Thought and Action vol. 11, Fall 1984, pp. 9-21.

[3]David Noble, America by Design, New York: Knopf, 1977; Henry Etzkowitz, "Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science," Minerva XXI, Summer 1983, pp. 198-233.

now the great engineering-oriented universities such as MIT, RPI, California Institute of Technology and Georgia Tech.[4]

Modern science entered the curriculum of the old elite universities as "natural philosophy." These universities strongly resisted any notion that the training they provided was to be "practical." In contrast, the land grants and technical schools were inclined to stress the applied and the useful. Yet, these institutions were frequently ambivalent. On the one hand, their mandate emphasized applied science; on the other hand, their faculty and government officers looked toward the more traditional, and prestigious institutions for guidance. As theoretical science gradually became a central part of the curricula in the older institutions, the land grants tended to follow. A considerable diversity evolved.

Cutting across these differences in university cultures are significant variations among scientific fields in terms of their intimacy with practical applications. Some sociologists of science have used theoretical physics as an example of a field where there is a sharp split between the philosophical and intellectual concerns of academe, and the practical concerns of industry.[5] However, historians have pointed out that the field of thermodynamics arose largely out of curiosity about how engines worked. Certain important areas of contemporary theoretical physics, for example, the study of materials, are closely connected with practical concerns. Nonetheless, for many fields of physics the characterization of the sociologists does ring true.

Academic chemistry, however, has from the beginning been closely tied to industrial chemistry. Chemistry, as a field, took hold in universities in the United States at about the same time that the U.S. chemical industry was beginning to grow. From the late 19th century on, professors of chemistry have served as consultants to chemical firms, often moving back and forth between industry and academe. Chemistry undergraduates then and now have found their careers largely in industry. Arnold Thackray describes how Ph.D.-level training in chemistry in the east

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[4]The published literature on the history of American research universities is scattered. Roger Geiger's new book pulls much of it together. See his To Advance Knowledge: Growth of American Research Universities 1900-1940, Oxford University Press, Oxford, 1986.

[5]While Derek Price often referred to science in general in his argument that science and technology develop independently of each other in terms of the purposes and agendas, his discussions almost always concerned physics. See for example, The Nature of the Scientific Community, Yale University Press, New Haven, 1980.

coast universities was initially a closed academic circuit. But he describes, as well, the training of industry-oriented Ph.D.s in the land grant colleges and technical schools.[6]

Much of modern biology is, of course, deeply rooted in the search for solutions to practical agricultural, medical, and industrial problems. Similarly, computer science, by the very nature of the subject, is closely tied to applications. And, of course, the set of applied scientific fields which call themselves "engineering disciplines" are directly oriented to applications.

This historical perspective is intended to stress two points. First, propositions about a natural chasm between academic science and industry science have often been drawn too sharply and too globally. Second, these cultures have been living together for a long time. Indeed, academic science and industrial science in the United States grew up together.

If scientific fields differ in their linkages with industry, industries also differ in the extent to which the development of their technologies is connected to academic research, and in the extent they are dependent on academic training of employees. In the 19th century, industries where "mechanical engineering" was the dominant technical skill depended mainly on practical on-the-job experience. Academically-trained mechanical engineers had a difficult time gaining acceptance in these industries. In contrast, from their beginning, the chemical-based industries and those concerned with electrical phenomena and apparatus turned to universities for scientific training of their technical employees. Early on, both of these industries established close contacts with technical employees and close contacts with technical schools, like MIT.[7]

Industry interests in academic research are not static. While academic scientists played an important role in the early days of the modern electrical industry, the work done in industry later came to stand largely on its own. In the early days of semiconductor and computer technologies, university researchers were heavily involved in research relevant to industry. However, industrial R&D on transistors and later integrated circuits gradually became quite separate from work done at universities. In contrast, academic computer science departments continue to do work that is highly relevant to industrial R&D.

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[6] Arnold Thackray, "University-Industry Connections and Chemical Research: An Historical Perspective" in National Science Board, University-Industry Research Relationship: Selected Studies USGPO.

[7] Noble, op. cit.

For the past quarter of a century, certain parts of academic biology and biochemistry have been very important to industry. University research has pointed the way to new drugs, and pioneered many of the important techniques in pharmaceutical R&D now employed by corporations. At the present time, corporate R&D in biotechnology draws heavily on university research, and the techniques and instrumentation developed at universities.

The nature and strength of university-industry connections vary with the traditions of the university in question, the scientific discipline involved, and the industry. They are also influenced by the sources of university funding, and prevailing attitudes about the appropriate roles of universities, business, and government.

During the 1920s and 1930s, private foundations were the dominate external source of university research funding. While those who made decisions about funding emphatically believed that the objective was to benefit mankind and made their decisions accordingly, they also believed that the appropriate role for universities was to do basic research. With few exceptions, the foundations looked askance at university work that was close to commercial interests, and at universities that seemed too cozy with industry. Their attitude reflected and sustained the notion that a relatively sharp line should be drawn between university laboratories and industrial R&D.

After World War II, funding for research increased dramatically. The federal government became the dominant external source of research funding at the universities. Industrial support also grew, although at a more gradual pace. In the NSF and NIH, academic researchers themselves played a principal role in allocating funds. Although this arrangement reinforced university values calling for distance from business interests, government funds were often justified by the argument that focused academic science was the key to practical progress.[8]

University faculty members and facilities also played a major role in military research and development during both the first and second World Wars. During the post-World War II period, the Department of Defense, the Atomic Energy Commission, and, to a lesser extent, NASA, were major supporters of R&D at universities or of facilities associated with universities. The projects sometimes called for interaction between

[8] Harvey Brooks, The Government of Science, Cambridge: MIT Press, 1968.

university and corporate research and development, and in a number of instances, the university researchers developed links with business firms, or set up firms of their own.

Thus, during the 1960s and 1970s, the sources of funding tended to support the notion of a separate academic research enterprise, but at the same time tended to pull parts of the academic enterprise into closer contact with business. As a result of the research funding patterns, certain universities came to be defined as research institutions, with long term consequences for the balance of interests within academe. These trends set the stage for the development of the new industrial alliances and also for the ambivalent reactions to them.

What lies behind the recent surge of new arrangements among universities and industry? During the 1970s, universities became increasingly aware that in many fields the cost of doing research was growing at the same time that federal support was in danger of decline.[9] It is natural that the attention of university administrators and researchers should be drawn to industry. The experience with Route 128 and Silicon Valley came into focus as potential models.

Developments on the industrial front led industry to reciprocate the interest in new and strengthened connections. During the 1970s there developed a growing perception and fear that the United States was losing its technological primacy in a variety of industries where we had become accustomed to unquestioned leadership.[10] At least two areas of cutting edge technology--computers and biotechnology--were recognized as closely linked to academic science. It is noteworthy that a non-trivial fraction of the new industry-university arrangements are involved in these two fields.

The relative decline of American industry soon became a matter of wide spread popular concern, affecting both federal and state politics. The question of how to link industry and university research, and the presumption that this was a good thing to do, lay behind a variety of new policy departures. At the federal level, the Patent and Trademarks

[9]Donald Kennedy, "Government Policies and the Cost of Doing Research," Science 227, 1 February 1985, pp. 480-484.

[10]President's Commission on Industrial Competitiveness, Global Competition: The New Reality, vol. II, Washington, D.C.:USGPO, January 1985.

Amendment Act (1980) and the Stevenson/Wydler Technology Innovation Act (1980) are particular cases in point. The Patent Amendments allowed universities to own patents resulting from federally-sponsored research for the first time. Federal agencies such as the NSF developed programs with the objective of forming industry-university cooperative projects.[11] A number of states initiated programs to encourage universities to support the development of state and regional high technology industry.

While there has been a long history of interaction between universities and industry, the new situation involves an explosion in the number of alliances and qualitative changes in their form. They have been created for different reasons, but in every case they involve an element of faith that they will be good for business, helpful and appropriate to universities, and in the public interest. Whether or not this faith is justified remains an open question. It is apparent that the nation is engaged in an experiment, and the stakes are high.

Kinds of Organizations Involved and Kinds of Alliances

There are many kinds of organizations involved in the new alliances, and many forms of alliances. At the governmental level, the National Science Foundation is active in sponsoring alliances in the form of industry-university cooperative research centers and projects and engineering research centers. The alliances involving medical schools and computer science departments draw heavily on capabilities developed through NIH- and DoD- funded programs. There are now a number of state programs organized with the express purpose of facilitating and supporting new alliances. Prominent among these latter are the Ben Franklin Partnership Program of Pennsylvania and the New Jersey Commission on Science and Technology, both described in the Appendix to this report.

Companies have organized themselves in a variety of different ways to fund and participate in these alliances. In some cases, industries have formed funding consortia. This is a good characterization of the Semiconductor Research Corporation and the Council for Chemical Research, both of which finance research in a number of universities. (For descriptions, see the Appendix.) In some cases, corporations have been

[11] National Science Foundation, Cooperative Science: A National Study of University and Industrial Researchers, November 1984; J.D. Eveland, "Communications Networks in University/Industry Cooperative Research Centers," National Science Foundation, March 1985.

formed with the expressed purpose of working with and drawing from university research. The Appendix describes Centocor, Inc. and the Neogen Corporation which fit this bill. Some large research and development intensive companies, like IBM and Monsanto, are involved with programs at several different universities.

On their side, individual universities may be involved in several different types of arrangements at the same time, some with government funding, some without, some with multiple corporate sponsors, and still others funded by a single company. And several universities may come together to jointly participate in an alliance with industry.

Obviously, all kinds of combinations are possible and exist. Relatedly, one can describe the spectrum of alliances from a number of different angles. By and large, the inquiry by the Research Roundtable Working Group reported here and in the Appendix, which served as the basis for the conference discussion, chose to look at alliances located at universities or groups of universities as the units of observation. Thus, the Group studied the alliance between Monsanto and Washington University at St. Louis, but did not explore in any depth either the other university alliances of Monsanto, or the other industry alliances of Washington University. The Group did not explore the portfolio of projects associated with the Semiconductor Research Corporation or the Council for Chemical Research, in any depth. Nor did it look at the portfolios of the state programs, although some of the alliances studied received partial support from them.

While in some sense this particular angle of analysis represses diversity, it also sharpens the focus on it. Study of the university programs described in the Appendix reveals an enormous amount of diversity. Below, this diversity is mapped out, first, by exploring variation in important dimensions, and second, by attempting to identify certain analytically-relevant clusters within these dimensions.

Dimensions of Variation

Activities. The partnerships vary considerably in the activities involved. Some are largely concerned with basic research. In other arrangements, the work is largely applied, intended to solve or illuminate a well-defined practical problem. Some involve very little research on the part of academics, but rather, are focused on providing consultation or other help to a company, under academic auspices. Many, but not all, are associated with the training of undergraduates or graduate students. In some cases, constraints are imposed to limit faculty entrepreneurship, while in others, the arrangement is designed to channel and facilitate that entrepreneurship.

Goals and Expectations. The goals and expectations of industry and university participants reflect the nature of the activities. Some industry participants articulate their goal in terms of a "window" into a scientific field. Elsewhere, corporate interest is tied to particular product or process development.

There is similar variation in what academics are trying to achieve. Some simply want to augment funds for certain kinds of research or equipment. Some believe the arrangements will facilitate job-hunting by their students. Often faculty members indicate that better access to the world of corporate R&D enhances their own competence and knowledge. It may enhance their incomes as well through consulting arrangements. In fact, some of the new arrangements have been put in place to regularize or gain control over consulting and entrepreneurial activities of faculty, or to provide commercial and entrepreneurial opportunities for faculty to attract them to the university or to keep them from leaving for more lucrative jobs. In a number of cases, the university administration sees the activities as an effective way of carrying out their mandate of providing public service.

University Culture. Most of the arrangements we studied are located in parts of universities with strong applied interests; that is, engineering schools, medical schools, and chemistry or computer science departments. However, universities differ greatly in their attitudes towards what kinds of relationships with industry are or are not appropriate. Those with long- standing liberal arts traditions have customarily considered the sciences in terms of their contributions to knowledge rather than technology. They avoid relationships other than those which support basic research, and insist that university faculty preserve the lion's share of control. The technical universities like MIT and RPI have shown a greater willingness to engage in applied research with industry funding. And universities like Georgia Tech, which grew up with a strong commitment to community service, consider a range of activities, from business incubator programs to proprietary contract research, as part of their mandate. In other words, it is the university's culture that defines the range of activities considered appropriate.

Industry Culture. The nature of the alliances also is strongly influenced by the cultural characteristics of the companies involved. Companies with a strong research tradition are more likely to invest in the long-term potential of a window on particular fields of science--more likely to fund basic research in the knowledge that it may not yield direct economic benefits, or at least not quickly. Some may not want a window on a particular field, but are willing to fund academic research, perhaps through consortia of companies, to help maintain the scientific vitality of their industry and the supply of well-trained industrial scientists. Other companies may feel that basic research is not a sound risk for them, even if they can afford it, and prefer arrangements with academe that focus on work of more immediate commercial potential. Some may prefer to keep their R&D in-house, where they can control its pace and direction and need not be concerned about the division of whatever economic returns materialize. Companies tend to be quite sensitive to the antitrust laws and to avoid arrangements that may put them at risk.

Differences also exist across industry sectors as indicated by the differing objectives and operating styles of the Semiconductor Research Corporation and the Council for Chemical Research. Member companies of SRC pool their resources to support a multi-million dollar, highly organized research program in universities, while CCR encourages one-on-one diverse, decentralized, and smaller-scale research programs.

Organization and Governance. The arrangements we have considered differ significantly in terms of organization and governance. Those involving basic research are located in regular university departments or schools, and are closely connected with general academic activity. Others, for example, the incubators and the institutes for contract research, involve facilities outside the main academic organization.

The programs also differ in terms of the relative influence of the university and industrial participants. In some of the research partnerships, corporate sponsors often do little more than broadly define legitimate fields of inquiry at the time of funding. In others, corporate representatives sit on committees which screen, focus, and thereby influence the direction of research. In still others, the relationship is contractual, with the sponsor defining the objective quite closely.

Federal and state governments also are important players in some programs with roles ranging from simply providing funds, to actively stimulating university-industry interactions, to influencing program development, operations, and governance.

Funding. In many of the programs, corporations are the principal sources of financing. In a few cases, industry associations provide support. In some, university funds are up front, with hope that these can be recouped. In others, federal or state governmental funds are important.

Clusters

The nature of the activities, expectations, university and industry culture, and governance clearly are correlated. While one can find examples of partnerships in virtually all positions of the map, we tend to see certain recognizable clusters. Five are described below, but obviously there are overlaps between adjacent types.

Research programs or centers that support many research projects, and that are closely tied to general academic research and teaching activities. Included here are the Monsanto-Washington University partnership, the Cornell Biotechnology Program, the Stanford Center for Integrated Systems, the relationship between Massachusetts General Hospital Department of Molecular Biology and Hoechst, and the Exxon-MIT arrangement. These programs sponsor research that is germane to the disciplinary interests of the involved faculty, and is "basic" in the sense that it is expected to yield publishable scientific findings. Training of graduate students is part of these programs. While the sponsoring corporations may expect special benefits from the projects, and therefore may have some proprietary stake in the results, specific commercial product or process development is not involved. University units are protective of academic freedom, although they are also sensitive to the interests of the sponsor. Consulting activity and faculty entrepreneurship may result from work on a project, but are not integral to it.

There may be a single sponsor, multiple sponsors, or sponsorship through an industry consortium; however, there is an identifiable and stable clientele. Corporate influence is exerted through membership on project selection committees, but corporate funders do not directly or independently specify what is to be done. University faculty retains considerable, usually dominant, control.

Focused projects involving both a well-defined practical objective and intellectual goals. Projects of this sort engage a research team--often including both university and corporate scientists--working toward a well-defined goal of interest both to the sponsor and the faculty. The academics involved tend to be in fields like engineering, applied physics, or computer science, where advancing or confirming ideas is associated with creating or testing devices or systems. Only one of these is in the set of cases considered in detail--the relationship between Carnegie-Mellon University and IBM, which aims at developing a computer system appropriate for a university. There are, however, many such programs in universities supported by the Department of Defense.

Characteristically, the client, be it a corporation or a government agency, has a major proprietary interest in achieving certain results. The academic reputations of key faculty members are also on the line, with the project representing the testing of their ideas. The design of the project represents a combining of both interests. The project may be located in a university department or school, or at a research institute affiliated with the university, but regular university faculty are centrally involved in the endeavor.

Programs developed to help commercialize faculty research. The incubator program at RPI largely fits this mold, as does Case Western Reserve's University Technology Incorporated, and Engenics, (associated with The Center for Biotechnology Research, MIT, the University of California at Berkeley, and Stanford University). These organizations differ from traditional contract research operations within technical universities, in that their aim is to help faculty implement the fruits of their research; however, the two kinds of activities are related. For example, the Route 128 companies were first established by scientists and engineers who had been working at MIT on contract research projects. Centocor and Neogen also operate with this objective, but as freestanding, for-profit companies that reach into the universities to identify and develop commercially promising research and technology.

Programs or institutions organized to help clients, operating outside the university. This group includes certain incubator programs, for example at Georgia Tech, and university contract research laboratories. The service provided may be directed to industry or to a government agency.

The universities involved in this kind of activity tend to have a long tradition of public service and industrial collaboration, often associated with engineering schools. The programs are conducted in laboratories that have some administrative distance from the university, although access to university faculty and equipment may be important.

Free standing research institutes, linked to several universities. The Microelectronics Center of North Carolina and the Industrial Technology Institute of Michigan differ from the above organizations. While university officials are on their governing boards, they operate on their own, staffed largely by their own employees. In both of these cases, the distancing from a university culture was deliberate, with the purpose of making the operation more like a corporate laboratory or a contract research facility. However, both organizations depend on part-time participation of university faculty and other university resources.

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All industry-university alliances raise delicate questions about the proximity of the relationship and their effect on the culture and priorities of the university. Most sensitive are those programs that are connected to core university activities in an essential way. These and related issues were the focal point of the conference discussions and are treated in Part II.

PART II

DISCUSSION OF THE ISSUES

Part I provided the historical precedents to the current alliances and mapped their variety and diversity. The tone of the report now changes as we move on to summarize the highlights of the conference presentations and discussion. The issues are organized into five major sections: Financial Support for the Alliances; Goals and Expectations; Corporate and University Cultures; Innovation, Technology Utilization, and Economic Development; and Progress of the Alliances. At the conference, Howard Schneiderman, Chairman of Roundtable Working Group Three and Conference Moderator, posed questions to guide the discussions toward key issues. These questions are included as introductions to the relevant sections of Part II. The italicized text is post-conference commentary of the Roundtable Working Group.

The conditions that are breeding the new alliances were described in Part I. As Dale Corson, Chairman of the Research Roundtable, noted in his opening remarks, these conditions are likely to persist for some time and are likely to be regarded with increasing importance in U.S. science and technology policy. Congress, Corson warned, is going to eliminate the federal deficits "one way or another," no matter which party is in power. The nation, including the universities, faces a period of extreme financial stress.

Industry, moreover, continues to struggle. Conversations in Washington about the course of U.S. science and technology and which fields and programs will receive support, Corson reported, "all start with industrial competitiveness." The topic colors everything that is done in the arrangements addressed by the conference. He added, "If the academic and industrial communities are to meet this challenge, the types of collaborative activity we will be discussing today must be a central part of the strategy. The analyses and discussions that are part of this conference are intended to help all of us make these alliances as productive as possible."

Financial Support for the Alliances

Industrial Support

Overall, corporate support for university research--currently less than 5 percent of total support for academic research--will never exceed perhaps 7 to 8 percent, in the view of many participants. Industry funding for university research comes largely from corporate research budgets, which are nearly always quite small relative to development budgets, and are likely to remain so.

Still, corporate funding is significant at some schools and in some fields. Carnegie-Mellon University, for example, obtains 20 percent of its approximately $64 million annual research funding from industry. Much of this industrial support is for fundamental research, but some is for applied work. Georgia Tech also receives about 20 percent of its $100 million research program from industry. Larry Sumney, President of the Semiconductor Research Corporation, estimates that the consortium is funding nearly 50 percent of U.S. academic research on silicon-based integrated circuits. In fact, SRC was formed partly because the federal government in the late 1970s shifted much of its support in the field from silicon to more exotic materials.

Similar data for chemistry and chemical engineering were provided by James McEvoy, Executive Director of the Council for Chemical Research. A CCR survey showed that industry accounted for 11 percent of the total extramural funding of basic academic research in chemistry in 1985; in chemical engineering, industry accounted for 44 percent of the total extramural funding.

Conferee David Blumenthal, Executive Director of the Kennedy School of Government at Harvard, citing a survey he had conducted of over 100 companies involved in biotechnology, reported that these companies provided about $120 million annually to support academic research in the field. That amount is about 30 percent of aggregate industrial funding of academic research and about 20 percent of all extramural funding of biotechnology research in academe during 1984.

The Federal Role

Conferees agreed that federal funding of academic research is critical, both for the long-term vitality of research and graduate education and for attracting industrial support. Moderator Howard Schneiderman termed reliable federal funding for research "absolutely crucial for securing the future of the republic." At the same time, Schneiderman foresees no significant increase in federal funding for a long time, apart from adjustments for inflation. The Gramm-Rudman-Hollings legislation, or whatever means of federal deficit reduction comes to the forefront, will have a serious effect on federal as well as state government budgets. Budgetary problems make it even more imperative, according to Schneiderman, "that we learn how to get some hybrid vigor from our two cultures."

Alliances like those examined at the conference appear to be one means by which federally supported research is further enhanced by industrial investments. This leveraging effect was cited by discussant James Meindl Co-Director of Stanford's Center for Integrated Systems. He doubts that the Center's 20 sponsoring companies would have been interested in investing had not a large, federally funded research program already been in place. Discussant James Mathis, retired Vice President for Science and Technology at Exxon, attested to the value of federal support to the Exxon-MIT effort in combustion research. Exxon is a relatively modest contributor to an MIT energy laboratory that has been supported "very significantly by the Department of Energy and other federal agencies." "The federal government," Mathis believes, "is serving a very, very catalytic role in all of this." Thus, it appears that the cumulative effect of long-term, broad-based federal support for university research over the past 40 years is an important contribution to current university-industry alliances. The federal role goes beyond specific programs aimed at fostering such alliances.

A perspective on an additional federal role came from Richard Fruehan, Director of the Center for Iron and Steelmaking Research at Carnegie-Mellon University. Most of the industrial partners in the Center, he said, have abandoned long-term basic research for economic reasons; they look to the Center to do it. Because of the current financial status of this industry, however, it is unlikely to be able to provide the requisite long-term funding. "The federal government," Fruehan suggested, "is well suited to the role of funder where the industry involved is important to the nation at large and to specific local economies and cannot underwrite the cost of research on its own."

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The capacity of industry to assimilate advances in research is related to the internal technical capabilities of the industry. The Working Group feels that a breakdown in symmetry between the technical capabilities of cooperating companies and universities, as may be indicated in the case of the steel industry and the Center for Iron and Steelmaking Research, will inhibit the ability of the industry to transfer innovative ideas into technology. The Group stresses that internal industry R&D is an

important component of technological innovation and that industry must maintain its investments in research if it is to benefit from participation in collaborative programs. Participation in such programs cannot be viewed as a substitute for internal industry R&D.
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Sustainability of Funding

The sustainability of funding provided by various sources for the new alliances was raised as a question of national science policy by panelist Edward Barr, President and Chief Executive Officer of Courtaulds U.S. Developments Inc. and Chairman of the New Jersey Commission on Science and Technology. He noted that arrangements involving state support are subject to political strategies and decisions and that funding priorities may change as governors and legislators change and as state finances change. Similarly, industrial partners may change course or companies may decide that they are no longer interested in participating. Barr asked if it is good science policy to support academic research through mechanisms subject to these kinds of relatively short-term influences. Conferees' views of the issue appeared to vary with their circumstances.

Discussant Donald Beilman, President of the Microelectronics Center of North Carolina (MCNC), said the sustainability question is often raised at MCNC, but is less significant than it once was. MCNC gets two-thirds of its funding from the state and one-third from industry. Its mission is to implement an advanced research/manufacturing program in electronics that enhances the research and education capabilities of the five North Carolina universities in the program and contributes to economic development in the state. Beilman said the Center has gained recognition as an element of the state's university capability in microelectronics and related fields and it is having less and less difficulty explaining its economic benefits to state officials.

Massachusetts General Hospital has been concerned about sustainability from the beginning of its agreement with Hoechst, according to discussant Marvin Guthrie, Director of the Office of Technology Administration at MGH. The company is providing $70 million over 10 years to support a department of molecular biology. The agreement will be extended beyond this initial funding period in 5-year increments unless either party requests termination at the end of the second year of each 5-year period. Existing trust funds would support a department about half the current size, according to Guthrie. The hope is that, should the Hoechst arrangement end, the slack would be taken up by funds obtained in the normal manner from federal or other sources. Tenured scientists in the lab are paid through separate systems, which would be unaffected by the loss of the Hoechst support. Nevertheless, Guthrie said, MGH continues to be concerned and is waiting to see what happens.

Discussant Meindl argued that the desirability of short-term or long-term funding depends on the field involved. The history of the development of semiconductors and computers, he said, indicates that three decades of sustained industrial funding in academe is warranted, and he encouraged industrial sponsors to think in these terms. At the same time, he acknowledged that the current recession in the semiconductor and computer industries has affected the Center for Integrated Systems. The sponsors have held to their basic commitments, but the goals for incremental funding have not been met.

Relatively short-term funding was favored by discussant Hubert Schoemaker, President of Centocor, Inc. The company establishes collaborations with academic scientists to convert breakthroughs in basic research into health-care products, focusing on cancer and cardiovascular diseases. Basic innovation occurs in universities, Schoemaker believes, and the early stages of an R&D program offer plenty of room for collaboration with industry. As the technology matures, the effort begins to shift into industry, and opportunities for collaboration diminish. Thus Schoemaker thinks industrial funding should be sustained for the early stages--from 5 to 10 years. By then, he hopes that the academic scientists will have moved on to new ground that will be the basis for new areas of collaboration.

Industrial and state sponsors' interest in near-term results do influence the nature of and the level of support for the collaborative programs. Discussant Gordon Hammes, Director of Cornell's Biotechnology Program reported conversations with companies that have no interest in supporting academic research that does not promise "a specific product in the immediate future." Discussant Angel Jordan, Provost at Carnegie-Mellon pointed out that companies that invest $1 million or more in a program naturally tend to want results--not necessarily products, but something more tangible than scientific papers--in a period they think reasonable. Sponsors' dissatisfaction in this area, he said, has caused no cancellation of programs at Carnegie-Mellon, but may have limited the growth of some. Discussant Walter Plosila, Deputy Secretary for Technology and Policy Development for the state of Pennsylvania, believes an effort that entails continuing state funding and support must show some short-term results. Thus, the Ben Franklin Partnership Program of Pennsylvania fosters not only R&D, but a range of additional activities designed to speed the commercialization of new technology in the near-term. These activities include incubator operations for fledgling enterprises and efforts to attract venture capital for company start-ups.

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Funding of university-industry alliances should involve more than a commercial objective. Support must also be provided for maintaining the general university research capacity and for the growth of specific disciplines; industry must support research whose applicability is not readily apparent. The Group recognizes the difficulty that individual companies have in pursuing such a course of action, but feels that industry must contribute to the general advancement of science and engineering. Failure to do so may put the nation at risk.

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Goals and Expectations

Howard Schneiderman opened the discussion of goals and expectations for the alliances with the questions below.

1. What were the goals for the program by each institution at the time of its formation? What were the expectations of the participating scientists and engineers from each institution?

2. Have there been changes in these goals and expectations? If so, why? If not, why not?

3. What are the indicators of success of the program? Indicators of shortcomings? What program characteristics were responsible for the successes and the shortcomings? Has there been a need for changing the course of the program? If so, why? If not, why not?

4. What are your observations about the appropriate roles for each partner in your collaborative program? To what extent is there symmetry among the partners in your program in terms of the quality and quantity of the participating scientists and engineers and in terms of the roles in establishing program goals and expectations?

Reports on the collaborations represented at the conference indicated that, in general, they are working well. Participants seem to have managed matters by selecting partners and arranging programs best suited to their particular goals and responsibilities. The key to achieving these matches--often repeated during the discussion--is to "talk early and talk often."

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Members of the Working Group are not of one mind regarding how they read these affirmations that all is going beautifully. That the parties are getting along amicably is not in itself evidence that the work the parties are doing is proving valuable to both. Indeed in the judgement of many members of the Group, most of the new arrangements are too new to evaluate that matter. In terms of the value actually gained by the parties, some undoubtedly will prove very successful, but we suspect that a number of others will not.

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Both academic and industrial people reported that problems in partnerships have been solved without great difficulty. One such problem is the mutual skepticism that apparently has marked some collaborations at the outset. Skepticism was said to dissipate on both sides when the ground rules are clear and the parties have worked together for a time.

The preliminaries for a collaboration in basic research are illustrated by the arrangement between Massachusetts General Hospital and Hoechst. MGH wanted a world-class department of molecular biology, according to discussant Guthrie. It was to operate completely in accord with the procedures and policies of the hospital, including open publication and collaboration with other academic institutions. The research would be controlled by the scientists, not by Hoechst. The company wanted a window on the science primarily, but was also interested in obtaining patent rights and in training young company scientists. Agreement was reached, and the arrangement seems to be working. Guthrie reported, "We have all been amazed and delighted by Hoechst's hands-off approach."

A quite different program is the Advanced Technology Development Center at Georgia Institute of Technology. The Center includes an incubator facility with a building on the campus as well as other activities such as the development of venture capital and training of entrepreneurial people in business practice and marketing. The state wanted the university to establish the program to contribute to industrial development, especially in advanced technology, according to discussant Thomas Stelson, Vice President for Research at Georgia Tech. Georgia Tech considered it a desirable new service function, so long as the state provided enough support to avoid diverting funds from existing activities. The state agreed to do so. The university already had a large industrial research program, Stelson said, so the new interface with industry was not a major change or challenge.

Another perspective was outlined by discussant James Herbert, President of Neogen Corporation. The company sponsors contract academic research with short-term commercial potential for products in the areas of animal health and shelf-life of perishable foods. When Neogen approaches a university, Herbert said, both sides usually present a list of requirements: "Here are the things we will do, and here are the things we won't do." When the lists do not mesh well enough, the company drops the idea. "We are not out to reform anyone's internal policies," Herbert emphasized.

Related experience was reported by discussant Schoemaker. Academic scientists and their host institutions, he said, have quite different ideas regarding the ownership of intellectual property developed on campus. Scientists generating the ideas may feel that they have full rights to the intellectual property. The universities, which often have provided essential support for the development, may feel they also have some ownership rights. The office of licensing and technology at a university, in Schoemaker's view, is essential in reaching accommodation among the company, the investigators, and the institution. Centocor has walked away from opportunities when it could not establish ownership, and it usually has been because the licensing office has not been effective or because the university has unclear policies regarding the ownership of intellectual property.

Differing Views of Goals

Getting a program started requires coping with differing views of the attractiveness and the appropriateness of its potential goals to the institutions and individuals involved. This was the case with University Technology, Inc., a subsidiary of Case Western Reserve, according to discussant Thomas Moss, Dean of Graduate Studies and Research. The organization is designed to provide a creative outlet for faculty members who at some point may wish to see a development in their research move into commercial application. It has other goals, however, including faculty retention, making money for the university, and local and regional economic development. In any event, Moss remarked, if Case Western Reserve had tried to get everyone to agree on a clear set of goals for University Technology, Inc., the enterprise probably never would have started. Goals were identified, but they were articulated loosely enough to permit each interest group to see that its own goals were part of the enterprise.

Similarly, the state government and the universities had different visions for the Microelectronics Center of North Carolina (MCNC). The state saw MCNC as a critical component of an economic development strategy aimed at moving from agriculture and traditional core industry to new areas of technology and manufacturing. "The expectations of the universities were not very crystalline," according to the MCNC's President, Don Beilman. Consensus existed only at the very top level, where senior officials saw the facility as essential to establishing first-class education and research programs in modern electronics. With respect to the rest of the academic community, Beilman commented, "We have taken the last two and one-half years to try to crystallize the program and the expectations. We are still doing that; we will always be in a state of flux. The history of all of the institutions [here at the conference] is nothing but a whole series of experiments that continue to evolve, and I think ours will be the same way."

Pockets of Skeptics

Despite the apparent success of existing collaborations, they do not always enjoy unanimous internal support. One speaker commented particularly on heavily funded pacts between large partners. In all of them that he's familiar with, he said, both company and university invariably harbor significant numbers of skeptics. These non-champions of the alliance may not have flatly opposed it, but their attitude at best is "wait and see."

Faculty morale may suffer and jealousies arise because of funding imbalances resulting from industrial collaborations. Jealousies among the haves and have nots, it was pointed out, are not new and may exist regardless of the sources of funding. The industrial contribution to tensions, however, can become significant at a school like Carnegie-Mellon, where company support has reached 20 percent of total research funding. The university has an additional problem, according to discussant Jordan, because it is having to use the industrial money for research and university money for the "bricks and mortar" needed to house it.

A related, but more positive experience with faculty support was outlined by discussant Hammes. The charter for an enterprise like Cornell's Biotechnology Program must be approved by the faculty, which resulted at one point in a two-hour debate in the equivalent of the faculty senate. Its tenor is suggested by an historian's statement that, "I don't see why Cornell should be a farm club for the industry." Nevertheless, the measure passed by about 50 to 1. It was clear, Hammes concluded, that the entire faculty, not just the science community, sees the value of such opportunities and supports them, however grudgingly.

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The Information Technology Center, a joint venture between Carnegie-Mellon and IBM, is one alliance that has had some difficulties. In spite of the fact that the program has been judged a success by both parties, they both acknowledge the "growing pains" of the ITC. At the outset, this alliance was more development-oriented than research-oriented, and as such it may represent a case in which the goals of the university were not aligned with the goals of industry. Because of a commitment to cooperate, Carnegie-Mellon and IBM have continued their collaboration and both parties are optimistic about the prospects for continued success.

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Corporate and University Cultures

Much of the discussion at the conference revolved around issues that arise from the fact that the collaborative programs are operating at the interface of corporate and university cultures. A major theme running through these discussions was the great diversity and variety stressed in Part I of this report. Academic and industrial cultures and values are clearly different, but degrees of difference vary strikingly among individual schools and companies.

Participants have not found it necessary to compromise the cultures and values they deem essential to their institutional missions to any significant extent. This fact was emphasized again and again during the discussion based on the following questions.

1. What discussions were there prior to the formation of the program regarding the appropriateness of the activity for the institutions involved? What issues were important in these discussions? Who was involved? What were the weights given to the goals of strengthening the university, increasing economic activity, and enhancing the capacity for applied research and technological development within the given industrial sector?

2. What is the relative importance of the academic and industrial partners in establishing program priorities?

3. How are the rewards and recognitions from successful developments of the program distributed to the program participants?

4. How has the program affected the research, teaching, and service responsibilities of the university faculty? The responsibilities of the industrial scientists and engineers? How has the program affected the research environment (selection of research problems, extent of disciplinary vs. multidisciplinary research, morale of investigators, views of investigators toward the other sector, communication of investigators within and between the participating institutions)?

5. What have been the successes and difficulties in maintaining the traditional cultures of academe and of industry? What was responsible for the successes? Where have the major operational strains occurred? What were the causes of the strains? How have they been resolved? What would you recommend others do to avoid similar strains in their programs?

6. Are students and postdoctoral fellows involved in the program? If so, what levels, what is the nature of the involvement, and what has been the impact on the students? Does the program have any special impacts on foreign student participation?

Research Priorities and Management

A major concern raised by university-industry cooperation is that commercial values will divert academic research from its proper role, the search for knowledge. Research priorities in academe traditionally have been set by the working scientists. On the other hand, priorities no doubt are affected by the sources of funds. Interest in practical problems, as noted in Part I of this report, has distinctly influenced the allocation of public support of basic research, especially in engineering and medically-oriented sciences. Even so, able scientists can always find worthy problems when the field of choice is broad enough, as it generally has been with federal support. The fear is that commercial menus will be unduly circumscribed. Reports at the conference, however, indicated that such fears thus far are not warranted. The discussion did indicate, nonetheless, that the universities and industrial sponsors are in the midst of ongoing efforts to reach the right balance in the degree of control and management of research within the collaborative programs.

The hands-off attitude of Hoechst toward the Department of Molecular Biology at Massachusetts General Hospital is one example. The scientists are doing what they want to do, and the quality of the department is widely recognized. The arrangements are different at Carnegie-Mellon's Center for Iron and Steelmaking Research, Magnetics Technology Center, and Robotics Institute, but control remains with the university in these cases as well. The industrial sponsors are represented through advisory boards or steering committees that meet periodically. "We listen to the industrial partners," discussant Jordan said, "but the academics reserve the privilege and the right of setting the priorities."

Peer-Reviewed Research. Arrangements where research to be funded is selected by formal peer review of faculty proposals were also said to be working well. In the Monsanto-Washington University relationship in biomedical research, for example, a committee of 10 members, five from each organization, reviews faculty proposals once or twice a year. The votes never split along company-university lines, according to moderator Schneiderman. Rather, they reflect areas of research interest and degrees of confidence in the approaches to be used, very much in the manner of reviews by study sections at the National Institutes of Health. Schneiderman conceded that the scientists at Washington University are well aware of Monsanto's interests, but does not think the knowledge should distort academic priorities. He likened the situation to academic scientists "shopping the granting agencies" with proposals for research.

Discussant Hammes reported similar experience at Cornell's Biotechnology Program. The academic and industrial reviews agree almost unanimously on which proposals are best and which are worst, with haggling restricted to proposals of intermediate quality. Several times a company has expressed interest in having someone work in a particular area. In such cases, proposals were solicited from faculty members with research interests in the area, but with no guarantee of funding. Invariably, Hammes said, the scientists produced good proposals and "were very happy to do it.... Good faculty see new opportunities in everything that comes along."

Contract Research. A comparable view of the impact on academic research priorities was given by discussant Herbert of Neogen Corporation. In arranging for university research on a specific project, the company finds an investigator who is already working in the field of interest and simply enhances his or her program. This approach, Herbert believes, should have no negative effect on an investigator's handling of his or her academic responsibilities. One positive effect, he said, is that the contract work stimulates multidisciplinary research. To insure mutual understanding of goals and of the degree of management to be exercised by Neogen, the company has found it advisable to communicate with its academic investigators regularly--sometimes almost weekly--but has detected no resistance. Investigators seem to appreciate the collaboration.

An Earlier Industrial Model. Conferee John Burns, Adjunct Professor at Rockefeller University cited his experience at the Roche Institute of Molecular Biology as an indication that basic research and commercial values are not incompatible if handled properly. Hoffman-La Roche established the institute in 1967 as part of a corporate research center, but with its own charter, facility, and budget. The idea was that the scientists in the institute would decide what research they were going to do. Recombinant DNA and monoclonal antibodies were not in the company's vocabulary at the time, Burns said, but the institute became a leader in the development of those areas of science. In Burn's view, if the company had told the scientists what to do during the formative years from 1967 to 1970, it might have told them the wrong thing and nothing would have happened. Burns stressed the importance of creating the proper research environment and the right interaction in terms of transition from basic to applied. He also emphasized the importance of bringing young people into research. Since 1967, the institute has trained almost 500 postdoctoral fellows, a significant percentage of them from abroad.

Cautionary Views. Along with these and other optimistic reports, there also were conferees who expressed concern about research priorities. Clark Bullard, Director of the Office of Energy Research at the University of Illinois, contended that "it is obvious" that academic research is seeing a major change in that industrial problems rather than disciplinary peers are defining the direction of research. Problem-driven research is not new--federal mission agencies have been funding it for 30 years. Bullard does not think that federal support of problem-driven research is necessarily bad, but he believes it is wrong to think that current industrial funding will have only a small cultural effect proportional to its small monetary support. He noted other conferees' views that "industries are going to universities precisely with the intention of leveraging...these government funds." One result, he suggested, could be that universities will be serving a somewhat narrower public interest in terms of their research priorities than in the past.

Bullard also asked whether consensus among academic and industrial people on project-selection committees really demonstrates the absence of cultural clash. The real values, he suggested, are reflected in the questions posed i.e., the scope of the research to be funded, and not by the selection of proposals designed to pursue those questions.

Panelist Richard Nelson responded that the conference was "looking at some rather special arrangements." The programs are sponsoring quite basic research, but in fields where the lines between basic and applied are blurred. Electronics and electrical engineering, for example, have been interdisciplinary and applications-oriented for a long time. It is by no means clear, Nelson believes, that the reported consensus in project selection would occur in all fields of science or engineering. Still, although academe is experiencing heavy demand for applied work in some fields, he does not "at the present time see that as a sweeping university-wide problem." Nelson conceded, however, that real issues may exist in the universities' handling of collaborative programs, especially in biotechnology and electrical engineering/computer science.

Discussant Hammes contended that the major cultural change came after World War II, when the federal government began its extensive funding of academic research. Agencies like the Department of Defense and the National Institutes of Health, he noted, have long supported "really fairly directed basic research." In this light, Hammes sees current industrial support as "a small perturbation."

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The Working Group agrees with the view that many of the issues that have come to the forefront in the university-industry alliances first came into view when the Department of Defense started to fund research, some of it classified, in universities. Furthermore, DoD support of research at universities is presently significantly greater than industrial support of academic research and it is likely to increase more rapidly than industrial funding.

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Freedom of Communication

Another cultural issue raised at the conference was the effect of corporate values on the freedom of communication considered essential to progress in basic research. Many reports indicated that universities and industry have been able to reach accommodation on this score with little, if any, distortion of academic values. This view was not unanimous, however.

Constraints on Publication. Contemporary academic-industrial arrangements typically entail delays in publication at least sufficient to permit patent applications to be filed. Universities commonly require contractual limits on such delays, but they vary from 30 days to more than a year. Such constraints were considered a major issue when the new alliances began to spring up, but some conferees said they had become a non-issue. Discussant Jordan said the delay at Carnegie-Mellon seldom exceeds two months and that he knows of no major problem during the past half-dozen years at schools with which he is familiar. Moderator Schneiderman endorsed this view. He pointed out that, in a joint research program, the slowest step in the publication process is finishing the paper. Usually the results are known in plenty of time--often months in advance--to examine them before the paper is ready for submission.

Publication constraints were not considered a non-issue by all. One conferee contended that the issue has only been muted because universities have been adamant about resisting constraints, although some have been less adamant than others. He argued that universities should avoid proprietary research and the consequent restrictions on publication. The right model, he said, is to spin off research to businesses near the campus that can do proprietary research.

A related question concerned proprietary research and doctoral dissertations, which traditionally are expected to report original work and be defended in a public or semipublic forum. Discussant Moss responded that Case Western Reserve does not take industrial research contracts that cannot be used for student theses in one way or another. It does only research that has educational value and can employ students. Georgia Tech takes proprietary as well as classified research, but all student research is structured so that it can be available to the public--theses are put in the library--according to discussant Stelson.

Stelson cautioned against blanket policies; Georgia Tech looks at each program on its merits. The school has had one large classified project for 10 years with no problems. It is classified because the scientists may need access to classified information, and the sponsor wants to avoid a six-month delay to obtain clearance should the need arise. It never has come up, Stelson said, and the work thus far is "the most open project that you could have."

Informal Communication. Conferees indicated that corporate values are not generally hampering personal interchange among academic scientists and students, barring specific, unusual cases. A notable exception, apparently, is biotechnology, where--by coincidence or not--industrial funding is relatively high and commercial competition is fierce. The point was stressed in Part I. In addition, conferee Blumenthal reported corroborative results from surveys of faculty members. The responses indicated, he said, that the threat to free communication among scientists in biotechnology is real. The risks in general, he added, "may tend to get underplayed in this discussion."

Differing opinions were expressed about the extent to which academic scientists talk to each other in any event. Discussant Herbert reported his impression that they do not discuss really important work, especially with people in the same field, because of the race to publish first. He suspects that some of the constraints that Neogen asks for are more liberal than the constraints the scientists impose on themselves. Panelist Robert Burris, Professor of Biochemistry at the University of Wisconsin, thought that situation was atypical. In successful institutions, he held, people talk to each other very extensively. He cited Boss Kettering's view that, "When you lock the lab doors, you lock out more than you lock in."

Discussant Jordan concurred and expanded on the point. "The more you are involved in industry-university programs," he said, "the more interdisciplinary you are, the more conversations you have with industrial people, the more you publish and go together to conferences. The industrial-academic connection, if anything, has enhanced communication."

Educational Functions

Central to the new alliances is the universities' basic role in educating scientists and engineers for both industry and academe. All of the collaborations reported on provide for participation by students as well as by postdoctoral investigators. Students and postdocs are involved in research at Carnegie-Mellon's three centers, for example. Students hold part-time jobs at Georgia Tech's Advanced Technology Development

Center, although university policy limits employment of full-time students to 15 hours per week. More students are entering electronics and related disciplines through the Center for Integrated Sytems at Stanford and the Microelectronics Center of North Carolina, and more graduates are joining the industrial sponsors, according to discussant Meindl.

Conferees also asked about the participation of foreign students and postdocs in the collaborative programs. The practice appears to be common. The Microelectronics Center of North Carolina has many foreign students, discussant Beilman said, because it wishes to take advantage of the best available, so long as they meet the requirements of the Export Control Act. Stanford's Center for Integrated Systems has a similar rationale and considers each case on its merits. The Center for Iron and Steelmaking Research at Carnegie-Mellon tries to maintain a ratio of three students to one postdoc and to use U.S. students and foreign postdocs. The use of foreign postdocs is seen as a way to obtain information from areas such as Japan. Further, conferee Fruehan reported, "Foreign postdocs, unfortunately, often work harder and work for less money."

Concern with Change in Academe

Conferees raised a number of questions about particular aspects of the new alliances that might induce significant change in academe. The topics included traditional loyalties and incentives, funding from non-industrial sources, and pressures for development work in universities.

Faculty Loyalties and Incentives. The loyalties of faculty investigators to their institutions "are not very great," according to discussant Schoemaker. In Centocor's experience, he said, investigators are always seeking ways to defeat the university's system, usually the technology and licensing procedures, and often put the company in a difficult position. Academic scientists are motivated by the prospect of financial reward in his view. Remarks at the conference also suggested that financial motivation is not the only incentive in arrangements with industry, nor even a necessary one.

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The Working Group recognizes a change in faculty loyalties over the past 40 years. Prior to World War II, little funding was available outside the university, and faculty concerns were directed toward their own institutions. With the significant increase in federal support there came incentives for promoting individual disciplines and growth in *professional and scientific societies. Faculty loyalties were directed toward the disciplines and their colleagues in the relevant societies. Now, the potential for significant increase in academic salaries through alliances with businesses and the financial community may diminish faculty loyalties to their universities and their disciplines. The Working Group sees this as the exception rather than the rule, however; generally, faculty loyalties to science and engineering run high in spite of the possibility for individual financial gain.*

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The division of financial rewards from academic-industrial alliances varies considerably. In the arrangement between Monsanto and Washington University's medical school, for example, royalties are divided 40 percent to the department, 40 percent to the investigator's laboratory, and 20 percent to the dean of the medical school for discretionary use. No rewards go to individuals personally. The same is true at Monsanto; no royalties from a commercial development go to the scientist who made the original discovery. As a result, a young Monsanto scientist can work in a senior professor's laboratory on a joint project without feeling discriminated against if commercial technology emerges and he or she receives no royalties. The laboratory benefits, but not the professor personally.

The approach is quite different at Neogen, which typically owns the technology developed from its contract research at universities. The company is "almost insistent" that the university share in the profits from a development, according to discussant Herbert. It also insists that the principal investigator be compensated, by the university or the company, at "a proportionate rate that would make him or her want to work to be successful in a project."

Motivation was also touched on by discussant Schoemaker, whose company usually pays royalties to universities. Investigators of the highest academic standards, he said, have displayed "long-term and very serious" interest in products they have been involved with, and the degree of their interest is affected by the universities' handling of the royalties. Where a percentage goes to the investigator, the quarterly check from Centocor appears to be "an enormous motivator" of interest. Schoemaker said he gets calls before the end of the quarter asking, "How are we doing?"

Experience has been different at Case Western Reserve's University Technology, Inc. The university usually takes an equity position (but not a management position) in the firm that handles the development of a faculty member's discovery and splits royalties or equity 50:50 with the investigator. Faculty members who have been involved in the operation, according to discussant Moss, do not act as if "they want to maximize the money, but as if they really want to see their discoveries find some practical use."

Non-industrial Support. A second issue was the effect of industrial funding on scientists' ability to obtain support from other sources. Young investigators at Massachusetts General Hospital who are funded under the arrangement with Hoechst, for example, have no need to submit proposals to federal (or other) funding agencies. They had feared, however, that their lack of a funding track record would jeopardize their prospects with the federal agencies when they left the program and had to obtain their support independently. Discussant Guthrie said the problem was raised with Hoechst, which agreed that investigators may submit proposals to NIH a year or two before they expect to leave. In this way they can begin to build a track record and obtain funding that they may be able to take with them. No provisions are attached to the process. Hoechst simply has to approve each case individually.

A related question was whether federal agencies are likely to conclude that proposals from investigators with generous industrial funding should be bypassed in favor of those from competent people not so situated. The answer appeared to be "no." Moderator Schneiderman reported that scientists at the Washington University medical school have not been penalized because of the Monsanto program, which is funded at about $6 million per year. Panelist Burris supported this view. To think otherwise, he believes, would be to underestimate the intelligence and fairness of the people who review proposals for the agencies.

Pressure for Development. A third issue was the potential impact on universities if companies begin to depend on them to handle the development part of R&D. The specific concern was the hungry, second-tier universities under pressure from the state legislature to conduct development projects for local companies. This circumstance, it was agreed, would threaten the quality of the academic enterprise. The solution, panelist Barr suggested, is to insure that whatever programs are established, are soundly based on existing strengths of the institution and the state, and are designed to exploit their shared values in the best sense of the word. "We can have all the incubation centers and development and commercialization programs that we need," Barr believes, "as long as they are based on those principles."

Issues for Industry

Industrial sponsors and participants in contemporary alliances face issues of their own. One of them is the international competitiveness stressed by chairman Corson. A question posed was whether certain of the collaborations can be considered a kind of substitute for Japan's Ministry of International Trade and Industry (MITI), which by various means encourages Japanese companies that normally vie strongly with each other to work together, up to a point, in order to enhance their competitiveness abroad. Discussant Beilman thought not. He sees the U.S. alliances as a new and creative way to contribute to excellence in both academe and industry. But nobody, he believes, considers them a substitute for a major national effort like MITI.

Cooperation Among Competitors. Obtaining cooperation among competing industrial participants in academic-industrial alliances apparently is not a serious concern. One of the potential difficulties is conflict with antitrust regulations, which may sometimes favor cooperation with academe. Companies may be wary about joining forces in R&D projects, but not of pursuing the same work individually or cooperatively with universities.

Fear of antitrust problems initially hampered cooperation among the more than 50 members of the Semiconductor Research Corporation, many of whom are direct competitors. The fear has largely dissipated, however, according to SRC's Larry Sumney. The companies are now talking willingly about where the industry should be a decade from now and the kind of research needed to get there. SRC funds academic research designed to produce generic knowledge. One of its member universities, Sumney said, is formally assessing the ranges of information that can be considered generic as well as related aspects of competition among direct competitors.

Cooperation among competitors is not considered a serious issue at the Microelectronics Center of North Carolina. Companies take their chances, said discussant Beilman. They are basically looking for the essence of the technology and aim to develop it on their own. Stanford's Center for Integrated Systems handles the problem partly by focusing on generic science. The results of all research supported by the baseline corporate funding are in the public domain. If a company scientist at the Center makes an invention that results in a patent, the 20 sponsors cross-license it under an agreement entirely exclusive of the university.

Foreign Companies. A further issue for industry in its collaboration with academe is participation of foreign companies. Conferees expressed mixed views. Discussant Beilman said that the Microelectronics Center of North Carolina finds it "very beneficial for our program to work with U.S.-based companies." Discussant Meindl reported that two European companies are involved in the Center for Integrated Systems by reason of their holdings in U.S.-based sponsors. The important criterion in asking people to join the Center, he said, is whether "they will hire a substantial number of our graduates." Meindl believes that benefits can accrue from having Japanese or other foreign sponsors. Each case should be judged on its merits.

Massachusetts General Hospital was concerned from the beginning about aligning itself with a large foreign company, according to discussant Guthrie. And Hoechst, he observed, sustained much criticism at home when the pact was announced. MGH concluded, however, that the alliance would not jeopardize this country's technological base or health-care market. "Whether we turn out to be right or not," Guthrie remarked, "time will tell."

Innovation, Technology Utilization, and Economic Development

The conference devoted considerable attention to mechanisms that lead from basic research through technology transfer and utilization to technological and economic development. Moderator Schneiderman guided the discussion with the following set of questions.

1. What were the initial goals and expectations regarding the impact of the program on technological innovation and economic development? What was the rationale for the appropriateness of the program for the achievement of these goals?

2. Are there indications to date that the program has resulted in increased utilization of scientific and engineering advances and in enhanced economic activity? If so, what are these indications? What features of the program were responsible for these accomplishments? What could be done differently and better to increase the contributions of the program to technological innovation?

3. How are the economic benefits kept within the region where they originated? How do the collaborative programs contribute to the national well-being?

4. **What are the limits and appropriate expectations for the contributions of the collaborative programs to increased economic development?**

Conferees agreed that the process of technology transfer requires patience and a long-term perspective. The complexes at Silicon Valley, Route 128, and the Research Triangle, for example, required 20 to 25 years to reach their current state of development.

Personal Contact

A critical mechanism in moving innovation from universities into industry is personal contact. Conferee McEvoy stressed the importance of seeing to it that academic and industrial scientists talk to each other at the bench level. The Council for Chemical Research, he said, has a number of programs designed to promote such contact because "this is where we feel the major action is." Discussant Hammes reported that Cornell has tried newsletters, workshops, and other methods of technology transfer, but that person-to-person contact is by far the most effective. One way to achieve verbal exchange is to have industrial scientists work on campus. The process takes time--the stay at Cornell has been two years, typically--but has worked extremely well.

Regular personal contact has not developed as quickly as had been hoped, however, at least in some alliances. A sponsor of Cornell's Biotechnology Program, for example, was reluctant initially to send a visiting scientist to the campus for an extended stay, but assigned one after the first year. The sponsor now is said to consider a resident scientist essential to gaining the full benefit of its investment in the program.

Stanford's Center for Integrated Systems invites each of its 20 sponsors to assign one scientist to the campus full time. Thus far, only half of them have done so. The Microelectronics Center of North Carolina also has only about half of the planned number of industrial scientists working at MCNC, although the situation is gradually improving. The delay is due partly to the time required to reach agreement with industrial partners on rights to intellectual property. The most difficult problem in building participation at MCNC has been to make the program more attractive to faculty members involved, according to discussant Beilman. Creating a conducive environment is important; faculty are coming on board, but the process is slow.

Faculty Entrepreneurs

Faculty members with entrepreneurial instincts have proved most important in furthering aspects of university-industry cooperation and technology transfer. Formation of the three centers at Carnegie-Mellon, for example, was triggered by faculty members who saw needs in research and technology and enlisted the support of administrators in getting the ball rolling.

Creating outlets for bright investigators with commercial ideas is an important challenge for universities. Lacking such outlets, faculty entrepreneurs typically have done one of three things, according to discussant Herbert: they remain frustrated; they go to work in industry; or they set up a moonlighting operation with or without the knowledge of the institution. And in the third case they often fail because they cannot develop the business needed to go with the research. The desire to avoid such problems, Herbert believes, has helped to attract universities to Neogen's program.

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Faculty who leave a university to set up a company, or faculty who moonlight from the university, take a certain amount of risk in their ventures. Faculty who try to market their technologies through universities, however, are always not exposed to the true experience of risk-taking, according to the Working Group. These faculty need not put themselves on the line for their ideas as true entrepreneurs do.

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Discussant Moss pursued the theme of developing technologies while retaining faculty in the university. Case Western Reserve, he said, has plenty of technology with commercial potential, is prepared to invest in it, and can find people to manage and develop it. The problem has been that the pipeline from the faculty with the ideas into the commercial world tends to be "blocked up with all sorts of junk." University Technology, Inc. is designed, broadly, to clear the pipeline and so ease the transfer of technology. UTI does not look for significant change of attitudes in academe and industry--its intent, rather, is to capitalize on the many areas where their goals overlap.

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The Working Group warns that the impact of faculty entrepreneurship may change the ambiance of the university. Of particular concern is the student-professor relationship which is necessarily affected by the dual *roles of faculty marketing their inventions. Universities must be prepared to address such issues in order to avoid the consequences.*

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The Role of Patents

Speakers indicated that the universities' function in innovation and technology transfer has been enhanced by the Patent and Trademarks Amendment Act of 1980. The Act permits universities and small businesses to obtain patents on inventions resulting from federally funded research. It was noted that before World War II, universities were part of a chain that led from research to some kind of product. With the independence conferred by heavy postwar federal funding of research, they stepped out of that chain. Discussant Moss termed the legislation of 1980 "a brilliant strategy for getting universities into the chain. Having worked in the Congress at that time, I don't think it really occurred to anyone there that that was going to be the net impact, but it has been a very distinct impact."

Conferee David Padwa, Professor at the University of Colorado, reinforced the point. Increasingly, he believed, universities are thinking that the patents they can now obtain may give them a way to strengthen themselves financially by "intelligently and ethically becoming transactionally innovative rather than merely technologically innovative."

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The Working Group expressed the impression that royalty streams over the next 25 years will be insignificant compared to the total amount of research support at any given university. For example, the University of Wisconsin receives approximately $150 million from federal sources and approximately $4 to $5 million from the Wisconsin Alumni Research Foundation (WARF). (WARF provides funds for development of technologically useful products from the university's research.) The roughly 3% of the budget that the university receives from royalties through WARF has an impact, particularly because the funds have no strings. However, in terms of quantity, the funds are quite small. The Group sees the Wisconsin paradigm as typical; royalty streams, although desirable, will not become significant.

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Discussant Moss outlined measures designed to inhibit industrial partners from simply banking a university's patented technology. Case Western Reserve, he said, tries to draw partners into the very early stages of commercializing technology instead of licensing it. The idea is that once a company is committed to a development, it is much more likely to seek commercialization of whatever patents ensue. The school also seeks arrangements that call for due diligence in commercialization, while recognizing that the process requires a certain amount of time.

Impacts in Economic Development

Given the long-term nature of economic development, the contributions of alliances designed to support it may not be widely evident soon. Data for a few programs indicated that small companies, in fragmented industries in particular need the technical support that universities can provide. However, even a modest expansion of a large business can make university technical support desirable and can mean significant economic development . Conferees agreed that small companies should not be overlooked. The federal government's Small Business Innovation Research Program was said to have proved to be effective in stimulating university-small business interactions.

The Advanced Technology Development Center at Georgia Tech is a program geared toward university-small business interactions. Currently, ATDC involves 51 companies; 18 of them are using the incubator facility on campus. A number of companies have moved from the program into successful operation. Companies that apply to enter the incubator facility tend to be weak, and only about 20 percent are admitted. The failure rate among these companies accepted has been only 15 percent, which was termed "astoundingly low" by discussant Stelson. In addition, he said, the state of Georgia had no venture capital organizations 5 years ago, but five are now operating in the state.

The capabilities offered by the Microelectronics Center of North Carolina have been instrumental in the decisions of more than a dozen companies to build facilities in the state. Some have already been completed. The state estimates that investments by these companies will exceed $527 million and create nearly 6000 jobs.

The Ben Franklin Partnership Program in Pennsylvania makes a special effort to measure short-term results in economic development. Participants include 123 of the state's colleges and universities and more than 1700 companies. Research funded by the program has resulted in more than 25 patent applications and 12 patents. In its first 30 months, the partnership helped to create or retain 2600 jobs at more than 432 firms, including 184 start-up companies, according to discussant Plosila. It has attracted $29 million in venture capital to its funded projects--that amount equals the venture capital attracted by the entire state of Pennsylvania in 1983. More than 30 venture capital firms--a significant increase--have been established in Pennsylvania during the past 3 years.

Progress of the Alliances: Current Evaluation

The progress achieved to date by the alliances represented at the conference was reported to be generally good. An undertone of caution was evident as well, however. More tensions and problems exist, it was suggested, than were admitted to. Several speakers touched on the difficulty of eliciting negative evaluations of such programs. The people who know most about them are those who are directly involved and so have their reputations on the line. The consensus was that most of the programs are too new to permit sound assessment of their performance and their impacts on academic and industrial cultures. It seemed to be agreed, in fact, that proper assessment may only be possible retroactively.

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There is a growing mutual dependence among universities and industry for the conduct of research. For example, in the fields of biomedical research, engineering, and some of the physical sciences, the cost of instrumentation and facilities is becoming progressively prohibitive. In some fields, industry will never be able to attract and retain all of the talented investigators that they need. The only reasonable mechanism for research in the future will be increasing collaboration and the development of permanent alliances. From this perspective, the Working Group considers the alliances as essential to maintaining the strength of the science and technology base, and not solely as a vehicle for enhancing commercial development.

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Impacts in Academe

Collaborations with industry have produced a variety of changes in universities. Faculty members have gained a better perspective on the industrial sector. New fields of research have opened for investigators, and a rise in interdisciplinary research was reported by a number of conferees. Departments have been forced to do more strategic planning in research, and interdepartmental cooperation has been enhanced. The traditional functions of the university have benefited. New courses have been introduced, for example, in robotics and automation at Carnegie-Mellon. Strong output of graduates as well as scientific findings was reported for the Exxon-MIT program in combustion research.

Massachusetts General Hospital has a thriving department of molecular biology with more than 90 people, including some 20 graduate students. The Microelectronics Center of North Carolina has a major new facility; in addition, the stature of its participating universities in computer science and engineering has increased substantially. MCNC has developed a computer-aided design system from scratch; it is now in use at its member universities and 32 others. The incubator facility at Georgia Tech has proved to be a major image builder for the university. Companies are graduated from it in formal ceremonies, and the media turn out in force. Licensing agreements concluded through Case Western Reserve's University Technology, Inc., during the past 3 years have climbed from 2 or 3 per year to 16 to 18 per year; they have brought in more than $3 million in research funding.

The Ben Franklin Partnership Program in Pennsylvania has enhanced cooperation among the state's universities. A software institute established by the Department of Defense at Carnegie-Mellon was supported by a joint letter signed by the presidents of six of the state's major research universities. Five medical colleges and universities provided a pool of about 70 faculty members for a center established in Philadelphia by the National Aeronautics and Space Administration.

Impacts in Industry

The impact of the new alliances on industry is more difficult to assess, but a few specific examples were reported at the conference. Discussant Schoemaker says that Centocor, which commercializes developments originating in academic laboratories, is "overloaded with products" after five years of operation. The Washington University-Monsanto program has sharply increased the company's sensitivity to biological knowledge. Otherwise, Monsanto would never have spent $2.7 billion to buy the drug company G.D. Searle, according to moderator Schneiderman.

Eastman Kodak started a company in the biotechnology area a year or two after it joined the Cornell program. Discussant Hammes said he "would not be brave enough to say that was our influence, but certainly it did not hurt." In fairness though, it remains to be seen if Monsanto and Kodak made sound business decisions. Should either prove wrong, the effect on industry's views of cooperation with academe equally remains in question.

The Birth of Hybrid Institutions

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One of the current outgrowths in the trend toward university-industry alliance is the birth of hybrid institutions; those institutions that have goals, purposes, and policies that do not necessarily fit into either category of the two cultures, but represent a combination of the two. These institutions have long existed in certain fields, but recently have taken hold in many other fields. One example of a long-existing institution is the MIT classified research program. Examples of a different nature are the programs established in agriculture. Perhaps there are lessens to be drawn from the evolution of such long-standing institutions. A number of questions should be asked concerning these institutions such as: Where will hybrid institutions prosper? What are the consequences in having such institutions spawn around the university culture? How is hybrid vigor--the combining of the strengths of the two cultures--fostered?

In these hybrid institutions, the university and industry boundaries are vaguer. For example, Monsanto has laboratories located in the Washington University Medical School. University administrators and companies should continue to look for new kinds of institutions whose impact should necessarily be watched (for problems involving secrecy, salary structure, etc.), but whose development should also be encouraged.

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PART III

OBSERVATIONS AFTER THE CONFERENCE

by

Dorothy Nelkin and Richard Nelson

We learned a considerable amount about the new alliances in the study we conducted prior to the conference. Our knowledge about them was enhanced significantly by the discussion at the conference. However, for the most part what we learned confirmed and strengthened our prior view of the current situation.

One striking observation from our earlier research was emphatically reinforced at the conference. That was the enthusiasm of the participants for these arrangements, and their strongly expressed beliefs that good things would come of them. There were a few critics as well. However, unlike the critics who have expressed themselves in print, often espousing a point of view that the new arrangements are quite dangerous, for the most part the critics at the conference simply expressed a cautionary note. Their view was that there were several important issues that had not been thought through adequately, that it was too early to judge the results of many of the new alliances. While appreciating the enthusiasm and energy of those involved in the current experiments, we here want to join the critics in stressing that what is going on is still very much an experiment. And the experiments have yet to be seriously winnowed by history.

Some critics of the new arrangements have stressed their concerns that they jeopardize the role of universities as open institutions, and repositories of public knowledge. We think that enough information is in now to reduce, if not eradicate, these fears. Most universities continue to be aware that their principal mission is public science and education. While certain of the new arrangements we have learned about give us cause for concern, in our view the current threat to the openness of American universities lies far less in the new industry-university alliances, than in the increase in Department of Defense funded classified work conducted at universities, and a potential tightening of governmentally imposed constraints on free exchange of information.

We are more concerned about the rhetoric if not the substance of corporate influence on the allocation of university research resources. We place high value in the understanding that research priorities in scientific fields should be set to some considerable degree by working scientists themselves, on the basis of criteria internal to that field. Of course, "to some considerable degree" does not mean exclusively, especially in fields that are driven by concern with applications. The university research funding system as has grown up in the United States since World War II, by working through a variety of different funding sources with different attitudes and mandates regarding the matter, has achieved a sort of balance between internal and external criteria for funding.

The current rhetoric surrounding the new alliances sounds to us like a call for a significant increase in the weight of external, and in particular commercial, criteria relative to internal criteria. We would argue that the evidence supporting this call is not persuasive. Indeed, to our knowledge, there has been no real study of the issue. However, as we indicated above, our concern here is with the rhetoric, not the substance. We agree with those at the conference who argued that corporate funding of university research inevitably is going to account for a very small fraction of the total.

We are more cautious than many of the participants at the conference regarding how valuable the new partnerships are going to turn out to be for the corporations involved. To what extent is it sensible and responsible business strategy to tie into academia for certain kinds of research instead of doing the work in-house? While business gains by access to top-flight university people, the academic route reduces corporate control over research and limits the ability to appropriate returns. Universities are inherently leaky places. If proprietary rights are important, does it make sense to finance the work in academia?

But if corporations do not gain some sort of a special advantage through their funding of an activity in the universities, what is in it for them? Corporations can be philanthropic, but not to a large degree, and corporate philanthropy is highly vulnerable to hard times. Academics should not count on much of it. It should be well noted that many corporate executives, and prominent academics, during the 1920s and 1930s called for significant increased funding of basic research at universities, through the vehicle of corporate philanthropy. For reasons that should be well understood, that never came about. We only got large-scale external funding of academic research when the American people agreed that government should do that job.

Of the many different kinds of experiments that are going on, some will turn out to be successful for the corporate sponsors as well as for the universities. But a number of others, we believe just as strongly, are going to turn out to be worthless to sponsoring companies, and perhaps not very valuable for the universities involved. There is a lot of winnowing that will go on.

As our final observation we offer the following. The last half-decade has been a very unusual time. We have seen, first, huge government deficits, and then later clumsy and Draconian measures to get the deficits down. As a result, the conventional wisdom now is bearish on what government ought to and can be doing in the arena of research finance, as elsewhere. We also have seen a sharp rise in the value of the dollar which accounts for much of the perceived decline in the competitiveness of American industry, including our high technology industries. But sooner or later the government budget will come into balance, and the nation will again be able to discuss new government roles in the financing of the nation's research. And the dollar will get better into line, and American industry will not be as much burdened in the competitive struggle by its over-valuation.

When these things happen, interest in industry-university alliances will surely continue. But there is good reason to believe that a changed environment will significantly modify the way they are perceived.

APPENDIX A. DESCRIPTIONS OF UNIVERSITY-INDUSTRY PROGRAMS

Section A: Descriptions of University-Industry Programs Based on Available Literature and Discussion Sessions with Representatives of the Programs.

Section B: Descriptions of University-Industry Programs Based on Available Literature.

SECTION A: DESCRIPTIONS OF UNIVERSITY-INDUSTRY PROGRAMS BASED ON AVAILABLE LITERATURE AND DISCUSSION SESSIONS WITH REPRESENTATIVES OF THE PROGRAMS

BEN FRANKLIN PARTNERSHIP PROGRAM
Pennsylvania

The Ben Franklin Partnership Program was established as one of several initiatives from a statewide planning effort, Choices for Pennsylvanians, through which the state was to direct its own economic course. The program arose from the recognition that the state was under-utilizing its excellent higher education asset. The Ben Franklin Partnership Program, allows the state to act as a catalyst in modernizing and diversifying its industrial base through the creation of new firms and the expansion of existing firms--thus creating more jobs--and providing education and training to accompany these developments. The emphasis is on private sector support of applied research that is also concerned with "capacity building." Various aspects of the initiative have served as models for other successful state programs that are getting underway throughout the country.

Four Centers of Advanced Technology were established in different geographic regions throughout the state as consortia of business, labor organizations, research universities, and economic development groups in order to undertake multidisciplinary research. Funding is competitive among the Centers. It is dependent primarily on technical merit, but also on private sector support, project quality, economic impact projections, past performance in job creation, and other measures.

The Centers have three functions: joint R&D, education and training, and entrepreneurial development. Each Center selected its own program areas based on the potential for local job creation. The program is run by decentralized administrations at each of the Centers to allow focus on technical merit at the local level. Both the universities and the private sector have technical veto power at each of the Centers. All four of the Centers have focused effectively on their chosen areas although three have changed at least one emphasis since their inception. The key to the program is that the Centers focus, adapt, evolve, and cut off unsuccessful projects. These strategies appear to have become more sophisticated during the past 2 years. The Centers are required to report on progress three times per year under eight principle measures including the net number of firms created, firms expanded, and the net number of jobs created.

Pennsylvania is unique in that its existing universities' "bricks and mortar" are in relatively good condition. Therefore, financial support need not be directed toward renovating and building facilities and can be used for support of R&D, training, and entrepreneurial development. (The universities cannot use the state funds for indirect or overhead costs.)

The program supports university research in the form of challenge grants through a university or college consortium member. In 1982, the state provided $1 million as challenge grants requiring a one-to-one match from private funds. State support has increased to $21.3 million in the 1985-1986 fiscal year, with a match of $80 million from the private sector and other sources. Currently, Pennsylvania is actually leveraging about a $3.80-to-$1 match with industry. The state will not provide more than $750,000 in state funds to a given project and will not permit any one source to provide more than that amount to match any one project.

Patent policy states that the universities and industries work out their relationship on a case-by-case basis (exclusive versus nonexclusive licensing, transfer of ownership, etc.). The policy has a clause stating that patentable technology funded under the Ben Franklin Partnership Program must be manufactured or produced in Pennsylvania. If a new technology is not manufactured in the state, each Center must obtain financial payback from the manufacturer in the amount equal to the state support of the technological research.

As part of its charter for entrepreneurial development, the Program conducts projects in support of small business through entrepreneurial assistance to start-up companies, assistance in seeking federal SBIR aid, product development financial assistance, and development services to firms in incubators. The Small Business Incubator Loan program provides assistance to incubators for acquisition, rehabilitation, furnishings, and equipment. Sixty-one firms are now located in one of 18 Center-assisted incubator facilities. The program also underwrites the cost of feasibility studies and services to tenants in incubator facilities.

As part of its education and training development activities, the program provides $3 million in state support to purchase modern equipment for teaching future engineers. The state funds must be matched with $9 million in private funds.

During the first 26 months of existence (March 1983-April 1985), the Partnership has been successful in job creation and other concerns.

One hundred twenty-three of the state's 135 universities participate in the program. Over 1700 industrial firms currently participate in the partnership and over 300 projects have been sponsored. The program has assisted 432 firms, including 184 start-up firms to create or retain over 2400 jobs. Research funded by the program resulted in the filing of more than 25 patent applications and issuance of 12 patents. Over $22 million in venture capital was committed to Partnership-sponsored projects. Thirty venture capital firms have been established in Pennsylvania, a significant increase over the last 3 years.

Over 24,000 people have attended Ben Franklin Partnership workshops for entrepreneurs. Program experts provided consulting services for more than 4200 people, evaluated almost 300 new ideas/inventions, and helped over 500 people apply to the Federal SBIR Program with 16 successes. With the assistance of the Ben Franklin Partnership Program, Pennsylvania currently ranks fourth in the country for receipt of SBIR awards. Almost 7100 students have graduated from Center-assisted programs which evaluated 558 courses, developed 336 educational/training programs, and modified 163 existing programs. The reporting system for these figures is such that the state will continually be able to monitor the realization of the Program's initial goals with relative ease; a rather unique feature among the state initiated technological innovation efforts.

COUNCIL FOR CHEMICAL RESEARCH

Concerned that the U.S. remain internationally competitive in chemistry and chemical engineering, M.E. 'Mac' Pruitt, former vice president for R&D at the Dow Company, stimulated the years of discussion between the university and industry communities that were behind the establishment of the Council for Chemical Research (CCR). Part of the discussions touched on an awareness that, since World War II, industry and universities have not understood each other's orientations and goals, particularly in "pure" chemistry. Another element of the discussions was the role of "collective research"--various industries pooling funds to support research ventures--in international competitiveness.

Out of these discussions, CCR was born in 1980. CCR's objectives are to fund basic research in chemistry and chemical engineering for the continued health and vitality in these fields; to create an environment conducive to invention and innovation; to improve industry-university cooperative activities; to ensure advanced education of the highest quality; to keep tabs on government regulation of industry and university research; and to promote government sponsorship of more speculative research, as well as for equipment and facilities. The concept was to establish a Central Fund of $600,000 to be distributed among universities on a proportional basis according to the institution's number of Ph.D. students in chemistry and chemical engineering.

CCR is a nonprofit consortium of 45 companies, including most major oil and chemical firms, and 145 universities. These members represent more than 75 percent of the R&D in chemistry and chemical engineering in this country. Annual membership dues of the voting representatives are $1,000 for universities and $5,000 for industry memberships. (Up to three additional participants from each member organization can participate for an additional fee.)

In 1984, CCR earmarked $630,000 for member universities to support basic research in chemistry and chemical engineering. Gifts to the Central Fund from 20 member-companies ranged from $1000 to $29,000. The funds are distributed through CCR's Chemical Science and Engineering Fund to heads of chemistry and chemical engineering departments as discretionary funds.

CCR is managed by a Governing Board of 18 members elected for terms of three years. Half of the board represents industrial members and half comes from member-universities. Six Governing Board members are elected to sit on the Executive Committee as Council Chairman, Vice Chairman, and four Directors.

A number of internal committees have been established to promote CCR's goals. The University-Industry Interaction Committee acts as a formal communication link between the two sectors. Some of the key activities of this committee include: assisting corporate members in providing support for Presidential Young Investigator (PYI) Award recipients (as a result, matching grants of approximately $1 million were given to 34 PYI recipients); maintaining profiles of effective cooperative research interactions; writing a primer on university-industry patent and licensing agreements; maintaining a faculty data base of member universities by interests and expertise; setting up CCR information stations at all member universities consisting of corporate profiles and company descriptions; and establishing exchange programs between departments and industrial laboratories. (For example, CCR arranges technical seminars by assistant professors from member universities at member company R&D facilities.) One result of the of this Committee activity has been the catalyzing of industry contracts with universities that are above and beyond CCR sponsored research.

Three other active committees of CCR include: the Scientific Advisory Board which advises CCR on scientific matters including industrial and national priorities in research; the Scientific Manpower Committee which maintains current data on the supply and demand for chemists and chemical engineers and recommends programs to encourage careers in these fields; and the Government Relations Committee which evaluates the effect of government policies and regulations on research and innovations in industry and universities.

Annual meetings provide a forum for exchange of ideas between industry and university members of the CCR. In fact, the meeting also serves as a place where chemists and chemical engineers can exchange ideas. Previously, these groups had not had much interaction. Communication also occurs through Chem=link, a CCR publication describing technical opportunities in chemistry and chemical engineering.

CCR has increased industry's awareness for the need to support basic research. Nationwide, industrial funding for academic chemistry research has increased 79 percent from $14 million to $25 million from 1981 to 1983. Corporate funding for academic research in chemical engineering has increased 100 percent, from $13 million to $26 million.

CCR recognizes that the bulk of financial support for chemistry and chemical engineering will continue to be awarded through federal granting agencies. Therefore, while not a lobbying organization, CCR is interested in learning how to participate in and influence trends in Washington. This is part and parcel of the organization's emphasis on promotion of the health of chemistry and chemical engineering.

GEORGIA INSTITUTE OF TECHNOLOGY INCUBATOR PROGRAM

Georgia Tech was originally established in 1885 to rebuild industry after the Reconstruction. This context is important because the culture of the university has been shaped by its long tradition of applied research and industrial outreach; Georgia Tech is "on line with industry." The engineering experiment station, an important activity on campus since World War II, is organized to promote industrial research. Thomas Stelson, Vice President for Research, summarizes the university's attitudes: "Georgia Tech wants to work with industry...many other universities conduct research supported by the private sector, but few are as active or as sponsor-oriented." Of the $85 million Georgia Tech spends on research, 20 percent comes from the private sector, a considerably higher percentage than the national average. This is the context of Georgia Tech's Incubator Program, hardly a new concept, but simply a new form of long-standing practice.

The Incubator Program is part of the Advanced Technology Development Center (ATDC), an organization formed at Georgia Tech in 1980, with support from the governor and the general assembly to promote high-technology enterprises in Georgia. The state gives Georgia Tech $600,000 annually to run the Incubator Program. In effect, it is a state line item administered by the university for the state. The program is an outgrowth of the state's economic and industrial development activities which for many years have relied heavily on Georgia Tech for technical support. ATDC also operates a $6.1 million technology business center and supports annual high-technology venture capital conferences, bringing together investors and new high-technology firms.

The Incubator Program provides support services to help entrepreneurs launch new business ventures in high-technology industries. The support services include laboratory and office space (for a nominal fee), access to equipment and technical assistance, financial and managerial advice, and help in raising capital. The start-up companies also enjoy involvement in seminars and other aspects of university life, credibility through their association with Georgia Tech, and access to the student talent pool for recruitment.

There is little concern about conflicts of interest, the balance of industrial influence over the educational and research projects, and proprietary issues. The "memo of understanding" for participation in this Program does not address these potentially controversial issues except in the most general terms. Problems have been worked out in the context of past projects and on a case-by-case basis using existing university policies. For example, all research work resides with Georgia Tech and is subject to the same rights as dictated by the National Science Foundation or other government sponsors of Georgia Tech research. There is no concern about conflicts of interest when scientists assume dual roles as professors and principal investigators in incubator firms. The only question that has been raised is whether these projects were contributing to the "oversell of high technology."

There are currently 18 companies in the Incubator building. An additional 33 start-ups have been admitted to the program, but are not actually located in the facility. As a state entity, Georgia Tech cannot hold equity in the start-up companies. The companies are permitted to donate stock to a philanthropic arm of the university, however.

After assessing the promise for technical and economic success, companies are admitted to the program for 6 months to 3 years. Approximately 20 percent of the start-up applicants are accepted to the ATDC. A number of these companies participating in the ATDC have been nourished to success.

Providing advice and support for the start-up companies goes beyond the public service concept for Georgia Tech. Two related reasons for the willingness of the university to promote this activity are the revitalization of Georgia in high-technology and the desire to increase the pool of activity close to the university. Currently, 62 percent of Georgia Tech's graduates leave the state, and the university is trying to shift that percentage. Georgia Tech recognizes that the Incubator Program has limited importance for its educational and research goals and will likely bring only limited funds into the university.

INFORMATION TECHNOLOGY CENTER
Carnegie-Mellon University/IBM

In the early 1980s, Richard M. Cyert, president of Carnegie-Mellon University, proposed that the university create a new kind of computing environment for its faculty, staff, and students. Cyert proposed that a network of distributed personal computers, based on the model developed within the Department of Computer Science, be expanded campus-wide. The university was using computing extensively in education and research, and the network was seen as a way of both providing computing services superior to those available through time sharing, and as a way of maintaining the university's national leadership position in computing. A task force was appointed to investigate extending such a network to the entire campus. The task force recommended development of a network of sophisticated personal computers, each with advanced graphics capabilities and virtual memory. These "scholar's workstations" would be linked to one another and to campus-wide data files, providing quick access to a wide range of information. Students would use the workstations with a variety of educational software.

Such a computer network was well beyond what was economically feasible for CMU at the time, and affordable personal workstations with the power envisioned were not yet available. Indeed, one of the purposes of the project proposed by the task force was to help develop the appropriate workstation for the next generation of university students and faculty. Cyert reasoned that the novelty of this plan might interest a major computer manufacturer in embarking on a joint development project with the university. For CMU, the project offered a way to improve its own educational program, to promote higher education, and to acquire prestige. For a manufacturer, the arrangement would provide a head start in the educational network for computers. The university began looking for a company to enter into a partnership to develop and deploy the "VAX on a desktop" initiative.

CMU's Department of Computer Science had strong relationships with many computer firms, so the university approached several vendors. Although other firms were not interested or not large enough to participate, Lou Branscomb from IBM indicated considerable interest in the initiative. At this time, IBM wanted to expand into the higher education market in a highly visible way in order to become the leading firm of computing systems for universities and to have access to the newest developments in technological approaches.

In July 1982, IBM and CMU began negotiations. A 3-year proposal was submitted to IBM for $3 to $5 million per year, with a 6-month notice-of-termination clause, to establish a 30 person software group (10 IBM employees, 14 CMU employees, and recruits from elsewhere), and to implement the system. IBM undertook a feasibility study on campus to determine if the objective was realistic. The two parties signed an agreement in October 1982.

The Information Technology Center (ITC) was founded to develop a network of powerful personal computers for use in university education. The ITC was chartered with developing "a software system, based on IBM hardware, that supports CMU's plans to integrate computing into its educational program." The vision of Cyert, Branscomb, and a few others at IBM, was essential for the success of the ITC.

IBM and CMU both made a commitment to pursue the project for a minimum of 3 years, with the intention of extending the agreement to 5 or more years if progress was satisfactory to both parties. The ITC is currently beginning Phase II of the project as a 2-year renewal of the initial agreement. After development, IBM stated its intent to assist CMU in deploying the system, on a university-wide basis, originally anticipated to start in the fall of 1985. The CMU system would serve as a demonstration project, providing a model for other universities and a showcase for IBM equipment and systems.

IBM agreed to supply all hardware needed for the development work at the ITC and CMU agreed to provide the software. CMU had access to IBM's most advanced technology so software that was developed would be appropriate for the equipment available in the late 1980s. CMU and the ITC staff would be obligated to protect IBM trade secrets.

Three months into the contract, it became apparent that certain IBM equipment offered as the advanced workstation vehicle was not adequate, and considerable energy was expended in attempts to create an appropriate system by adding functionality to existing IBM products. After about a year of unsuccessful attempts to convert an IBM PC into an appropriate piece of equipment, the decision was made to use non-IBM equipment on an "interim" basis. Workstations manufactured by Sun Microsystems were to be used by the ITC during the development phase; the software would later be moved to advanced IBM workstations prior to their deployment on campus. At about the same time, it became clear that the systems software for advanced function workstations developed in the Department of Computer Science (ACCENT) would not be appropriate for a widely deployed system or for a commercial product. CMU and IBM jointly decided to use the Berkeley

UNIX operating system (a product of Bell Labs and the University of California at Berkeley) and the DARPA communications protocol (developed by the Department of Defense).

IBM agreed to these technical decisions because of the needs of the ITC project. In the meantime, the responsibilities for administering the project from IBM's side changed from the Communications Product Division (CPD), a product development and marketing division, to a newly formed marketing division, the Academic College Information System (ACIS). With the shift in organizational responsibilities for the ITC project within IBM, came a corresponding change in the priorities attached to various project objectives or outcomes. Originally, the ITC's software development project was attached to the same part of the organization responsible for developing a potential IBM product on which the systems software would run. In ACIS, the project continued to be highly visible, but not directly relevant to any products currently being marketed through ACIS. ACIS has university interests as its priority. ACIS is charged with marketing IBM products to colleges and universities. As such, the CMU/IBM collaboration became more one of generating marketable IBM products for use in universities. ACIS officials were concerned that the system, developed on Sun workstations using a university-based operating system (4.2 BSD UNIX), and utilizing a DoD communications protocol (DARPA), would not necessarily become a uniquely IBM product. CPD officials responsible for developing the target workstation for ITC software within IBM considered the project interesting, but began to see it as somewhat less relevant to its own systems software development as part of its own product development plans. The transfer of the workstation project from CPD to another IBM division in early 1984 further distanced the ITC software development project from its intended hardware product.

A further complication was the growing awareness within Carnegie-Mellon and other research institutions in higher education, that no single company manufacturer, was likely to dominate the higher education market. Accordingly, Carnegie-Mellon, as well as nearly all major universities, adopted an explicit "multi-vendor policy" and embraced the adoption of various standards or "development targets" for the next generation of workstations in higher education and the supporting software.

IBM recognized the importance of utilizing common standards and protocols and the importance of the UNIX and DARPA communications standards in "bringing the computer science and professional software development community into the fold." According to John P. Crecine, Carnegie-Mellon Senior Vice President for Academic Affairs, several key IBM employees including Keith Slack, the first IBM project overseer, and his superior, Stew Elder, were responsible for deciding on the hardware and software choices to support the ITC's development objectives maximally. These people were deeply committed to the ITC's goals, often in spite of internal IBM opposition, and throughout, took a broad, collaborative view of the relationship rather than a "strictly IBM" view.

Product development at ITC takes place in a closed, competitive atmosphere because the ITC uses unannounced IBM products, and because the ITC itself develops potentially valuable software. The second floor of the building that houses the ITC is locked at all times. Only employees with magnetically-coded identification passes can enter, and initially IBM wanted to deny foreign nationals access to the ITC facility. While such measures may be common in industrial laboratories, they are not common on university campuses. As a result of the secrecy, CMU will be reluctant to do work with unannounced IBM products in future arrangements. During Phase II of this agreement, every effort will be made to minimize special access space to a few rooms. And the project is expected to become more development-oriented rather than to continue with applied research during this phase.

The ITC has experienced no conflict concerning the publication of research results, in part because ITC's principal output is software. The relevant issue, therefore, is the public release of the software in source code, rather than publication of journal articles. IBM currently owns all system software developed at the ITC. Though CMU will receive no royalties, the university has the right to use this software in perpetuity. Educational software developed by CMU faculty to run on the ITC's system--"ANDREW"--is owned by the university and/or the faculty member who wrote it, as long as it does not make direct use of ITC-generated code. CMU would like to see the software made available to other universities so that it can serve as a stable, dominant standard systems software base, upon which educational applications software is developed for advance function workstations in higher education. Given that "ANDREW" is built on top of 4.2 BSD UNIX, it is intended to be "hardware-independent." But, IBM is not enthusiastic about releasing software that helps other computer vendors sell machines to higher education.

According to Crecine, IBM is undecided about the release of software developed by the ITC. They do not want to put "ANDREW" into the public domain as is 4.2 BSD UNIX. They are not sure they want to make it an IBM software product, and license it for a nominal fee to universities, industries, and other company manufacturers in much the same way that AT&T distributes and supports UNIX. On this topic, the contract between CMU and IBM provides some protection for the university. CMU has the right to send tapes of the current version of "ANDREW" software to up to 10 commercial units (including computer manufacturers); it also has the right to distribute copies of the software to other universities if IBM chooses not to disseminate the work as a commercial product.

The history of the ITC points out the importance in considering the organization and culture of companies involved in university-industry alliances. IBM's internally competitive and secretive culture, together with its reorganization, had important influences on the evolution of the ITC. IBM views the ITC as successful, though they are unhappy that, at least in its initial form, the system will not look like an IBM product. IBM views the arrangement as an "image enhancer."

CMU also sees the project as a success, and believes that the software developed thus far is useful. CMU administrators recognize that the ITC entered into some areas more in line with industrial rather than academic roles. In the future, CMU would prefer that the ITC concentrate on research more in line with traditional university practices.

Conflict arose around technical issues, around the secrecy associated with the project, and around the issue of the release of the system software produced by the ITC's efforts. An additional unresolved issue faces the project as Carnegie-Mellon prepares to deploy the new system throughout the university. Although CMU has recently decided to use IBM technology and cabling for its 10,000-node network, there is nothing in the contract--Phase I or Phase II--that necessarily involves IBM significantly in deployment. Students, who will account for the vast majority of workstations in full deployment, are not required to purchase a workstation as originally planned. They will be free to purchase any of several workstations with the necessary functionality, each of which will be available in the university's computer store. The extent to which individual students decide to purchase non-IBM products will generate more-or-less a perceptual problem within IBM.

In spite of the current software release issue and the potential deployment issue, the joint CMU-IBM project has proven to be quite productive for both parties.

INDUSTRIAL TECHNOLOGY INSTITUTE
Michigan

In 1981, as governor of Michigan, William Milliken envisioned expanding and strengthening the state's economic base through industry-university interactions. An enlightened group of Michigan academic and industrial leaders convened under a Governor's High Technology Task Force to investigate the challenge. The group met briefly and recommended that the state look at alternatives for establishing an institute for university-industry interaction. After consideration, the Task Force recommended that the state establish a technology institute for durable goods manufacturing, and if sufficient funds and energy existed, also to establish a biotechnology center for the plant kingdom. Proximity to, and the economic importance of, the durable goods manufacturing industry was a major factor in deciding on the first initiative.

A subset of the Governor's Commission provided a $200,000 grant for the creation of a nonprofit institute located in Ann Arbor as a separate entity from all universities. Subsequent support came from the Kellogg Foundation ($40 million over 9 years--the largest commitment ever made by a private foundation) and the Dow Foundation ($10 million over 7 years). The state also supported this program ($17.5 million over 6 years in a single grant) and the Industrial Technology Institute (ITI) was established in 1982. Initial funding from the state and private foundations provided equipment, facilities, and operating expenses for about 100 people to establish independent centers concerned with the growth from basic research to prototype development.

ITI was organized to conduct basic and applied studies in technologies related to manufacturing-based industries (especially durable products), to assist manufacturers in using technology for improved quality and productivity, to forge partnerships between producers and users of durable goods technologies, and to provide R&D to assist industry, labor, and government in planning for economic and social adjustments that accompany technological change. ITI hopes to provide leadership in developing Michigan and the Midwestern U.S. into an international center for the new industry of engineering, production, and support of automation equipment and software for the "factory of the future."

ITI's roles and functions include performing basic and applied research in industrial automation and computer integrated manufacturing (technical, social, and economic implications); developing new techniques, sensors, algorithms, processes, and decision-making tools for the factory of the future; disseminating information on emerging technologies, social impacts, and economic analyses in automation both within ITI and externally; and fostering new industrial development in production of hardware and software for automated manufacturing.

Jerome Smith became President of ITI in August of 1983. He recognized the national need for establishing applied research centers to develop technology faster. In this regard, ITI was modeled somewhat after the Fraunhofer Institutes in Germany.

The current staff of 110 works with a $10 million budget, 20 percent of which comes from sponsored projects in 1985. Smith hopes that 50 percent of the 1986 budget will come from sponsored projects. Current space limitations prevent an increased staff, but a larger, permanent facility is under construction.

ITI has benefited from exchange with the University of Michigan and Michigan State. A high quality staff has been attracted to ITI in part because of its affiliation with the universities. Although only the president has a joint tenured appointment, other mechanisms for exchange continue to emerge including adjunct appointments in the engineering and business departments at the two universities. Staff teach courses and act as consultants at the universities, and they participate in seminars and research projects. ITI also supports some research at these institutions, but contrary to some misconceptions, it is not a grant administering unit. ITI currently has collaborative efforts with faculty and students from five universities within the state and three outside the state.

The new facility, to be completed in 1986, will be located within a mile of the University of Michigan's College of Engineering and will consist of ample office and laboratory space for more than 250 employees. The facility will cost $17.3 million to construct ($12 million from the state and $5.3 million to be raised from private sources). By 1993, the operation will be based on revenues from contracts, grants, and fees. The centers will be developed based on the ability to recruit senior people in each area of study.

ITI is organized into Five Centers and Laboratories:

The Center for Social and Economic Issues (CSEI) conducts research on the social, economic, and organizational problems derived from the implementation of industrial automation. Particular attention is focused on durable goods manufacturing, although much of the research has a broader scope. The four areas of study at CSEI are: quantitative forecasting of personnel dislocations due to automation; identification of organizational issues resulting from the use of advanced production methods; cost-benefit analyses of automated manufacturing methods; and the analyses of public policy and programs which will enhance or impede application of modern manufacturing automation. CSEI develops training programs, workshops, and conferences, and provides direct assistance to relevant constituents (e.g., labor unions, industrial firms, public agencies). ITI weds the social and technical scientists in this Center's research.

The Information Systems Center (ISC) is concerned with the dissemination of knowledge rather than the generation of new ideas. ISC is composed of three areas of focus: services for dissemination of information to ITI staff and clients; communications services which provides marketing public relations, conference, and information gathering services for ITI; and subscription information services for internal and external database development. (This latter revenue-producing research represents the majority of the staff at ISC.)

The achievements and products associated with ITI will be publicized through ITI's Communications Service of the ISC in the form of articles and newsletters targeted to the popular press, trade journals, and industry and government sponsors.

The Communications and Network Laboratory (CNL) focuses on the development of digital communication systems for factory control. In cooperation with General Motors and the National Bureau of Standards, CNL has been involved in the establishment of tools to assess conformance of products to the emerging Manufacturing Automatizing Protocol (MAP) Specification. CNL has developed the only MAP conformance testing laboratory to be recognized by the MAP Users Group, an association of more than 250 manufacturing firms. Another important aspect of CNL's effort is the development of software for integrated factory control. The focus is on the development of modular software for controlling several automation cells and the communication network through which they communicate.

The Flexible Inspection and Assembly Laboratory conducts research on minimizing the cost and time of assembly processes as well as minimizing errors in the processes. The laboratory is composed of three areas of research: product design anticipating automated product manufacture, automated assembly and inspection systems, and a Robot Evaluation Center to test the performance and new applications of robots.

The Flexible Machining Laboratory (FML) conducts R&D on the metal cutting process, materials handling, and production systems for metal removal. FML addresses issues such as flexible fixtures, adaptive control of machine tools, sensor development, hardware and software development for tool transport and storage, and software required for specific equipment in laboratories.

Research is conducted according to the approximate percentages outlined below. Fifty percent of research is near-term i.e., with applications expected in 1 to 3 years. This research is funded almost entirely by industry and concentrates on proprietary equipment and prototype development, specific one-of-a-kind software, etc. Twenty-five percent of the research explores potential implementation from basic research within 2 to 5 years, primarily as feasibility studies for adaptation to automated manufacturing, computer-based control, and diagnostic tools. This type of research has both industrial and government sponsors. And 25 percent of research will be of a basic nature with applications expected in 5 to 10 years, funded primarily by federal agencies.

Contract research for Industrial Affiliates can include a number of proprietary arrangements from nonproprietary research to the the situation where a company does not even want anyone to know ITI is conducting research for them. ITI tries not to put graduate students on any projects which might have proprietary constraints. Foreign companies must have a plant in the U.S. in order to participate in ITI's contract research.

The state supports ITI because it recognizes the effort to enhance and strengthen Michigan companies and to attract new firms. ITI is attempting to create the nucleation of the automated manufacturing systems industry in Michigan in much the same way as the automotive industry is based in the state. ITI is seeking to emphasize process rather than product technology in durable goods manufacturing and to demonstrate to these firms that they can tap into resources from "outside" groups like ITI. ITI is optimistic in becoming a world class recognized center for such research; over 7,000 industries are located within 100 miles of Ann Arbor. This geographic proximity will likely aid in ITI's attempts to assist industry.

MICROELECTRONICS CENTER OF NORTH CAROLINA

The Microelectronics Center of North Carolina (MCNC) is a private, non-profit corporation established in 1980 to support the technology needs and international competitiveness of the United States modern electronics industry and thereby complement North Carolina's state initiatives to enhance the U.S. position in high technology economic development and the economic health of the state. The mission of MCNC is to implement an advanced research/manufacturing program in modern electronics related disciplines; to build the educational and research capabilities of six participating North Carolina institutions; and to provide for the development of design and fabrication technology for manufacturing next-generation submicron integrated circuits. MCNC is structured to benefit the microelectronics industry as well as university educational and research programs.

As the first multi-institutional microelectronics center in the United States, MCNC combines the resources of seven North Carolina organizations: Duke University, North Carolina A&T State University, North Carolina State University, University of North Carolina at Chapel Hill, University of North Carolina at Charlotte, Research Triangle Institute, and the MCNC Central Laboratory.

The chief executive officers of the five universities and the president of RTI are all members of MCNC's board of directors. Additional members of the board include a state government representative, four residents of North Carolina, two others (appointed by the governor), and the president of MCNC.

The MCNC Central Laboratory, an advanced state-of-the-art research and technology development facility, complements the educational and research programs at the participating North Carolina organizations. To leverage available resources and encourage collaboration, the Central Laboratory operates a 250 mile microwave communications system with 2 interactive video and 16 T1 data channels. Extensive sharing of educational resources through teleclasses originating at the participating universities provides advanced microelectronics courses for graduate students. Teleconferencing capabilities and the data channels support joint research among all participating organizations. The design of the communications system will allow for expansion to other sites in North Carolina as the need arises.

MCNC is funded primarily through grants from the North Carolina Department of Commerce. Strong leadership from the Governor's Office and General Assembly of North Carolina has resulted in a total investment of $93 million, $81 million of which is in the form of direct State appropriations. This includes funds to construct, equip, and operate the Central Laboratory as well as program support to the five universities and the Research Triangle Institute. Over $40 million has also been invested in related new capital facilities on the university and research institute campuses.

The MCNC program integrates basic and applied research with industry requirements for commercial technology development. The Central Laboratory provides manufacturing technology capabilities for development of next-generation submicron integrated circuits having one million (Very Large-Scale Integration or VLSI) to ten million (Ultra Large-Scale Integration ULSI) transistors on a chip.

The state investment is leveraged with industrial contributions to support the MCNC program, which provides an efficient mechanism for funneling basic and applied research results at the universities and research institute into potentially useful commercial technology. There are currently over 30 companies providing support to the MCNC program. Seven companies (AIRCO Industrial Gases, GCA/IC Systems, General Electric, IBM, Monsanto, Northern Telecom, Shipley) are Industrial Affiliates, and help support sponsored cooperative research. The Affiliate membership fee is $750,000 for the initial 3 years, renewable annually thereafter. The fee can be paid in cash or by donating appropriate equipment, negotiated on a case-by-case basis. This opportunity allows Affiliates to test their newest equipment in a research setting. Only one supplier of a given type of equipment, however, can participate in the Affiliates Program. The MCNC program will eventually accommodate 15 to 20 firms as Industrial Affiliates.

Industrial Affiliates sponsoring cooperative research have early access to research results and assign up to three full-time company employees to work with Central Laboratory staff, faculty, and graduate students. Regularly, Affiliates help guide and review the technical program direction to ensure commercial relevance.

MCNC's Intellectual Property Review Committee establishes procedures for licensing, patent, and copyright arrangements. Generally, Affiliates receive nonexclusive intellectual property rights for 3 years.

The Intellectual Property is made available to Affiliates for external use on a royalty basis which encourages use of technologies and provides leadership opportunities.

In addition to the Affiliates Program, MCNC has other mechanisms for industrial interaction including Associates, Sponsors, and International Liaison Services Programs. Members of the Industrial Associates Program are generally interested in a specific product or process and participate in MCNC for the equivalent of $300,000 over 3 years, but do not have professionals in residence. There are currently four members of the Associates Program. Over 20 Sponsors--vendors for microelectronics research equipment and supplies--have given MCNC substantial discounts and/or donations. International Liaison Services are provided to foreign companies by directing the participants to appropriate campus resources, in lieu of technical involvement at the MCNC Central Laboratory. Currently, two foreign companies are using this service.

The educational community has increased its resources substantially since the creation of MCNC. The Central Laboratory significantly enhances the educational and research programs of the participating institutions by providing advanced capabilities not available on individual campuses. In turn, the Laboratory depends upon the university, as well as industry communities, for a significant portion of the total expertise for collaborative research programs. Participating university departments have experienced a 25 percent growth since associating with MCNC. The full-time staff of the MCNC Central Laboratory is now approximately 120. The participating institutions of MCNC include approximately 200 faculty/staff members and 1,550 graduate students in teaching and research programs in microelectronics related disciplines. There are 6,200 undergraduates in modern electronics related disciplines.

New facilities and teaching laboratories have been constructed at each of the participating institutions, some with substantial support from MCNC. Competitive research grants are provided to the universities in support of basic research of interest to MCNC and its Affiliate members. MCNC also assists the universities in obtaining external funding and manages large projects involving multiple institutions.

The MCNC program provides unique national resources in modern electronics. The 100,000 sq. ft. Central Laboratory, completed in the fall of 1983, contains 10,000 sq. ft. of class 1 clean space divided into three vibrationally-isolated sections to develop advanced manufacturing processes on the latest equipment. This facility, along with the talent and facilities at the participating campuses and strong involvement of industry, position MCNC to develop and provide technology required for manufacture of next-generation submicron integrated circuits.

Relative to MCNC's economic development impact, more than a dozen companies have announced plans to build facilities in North Carolina and some have already been completed. The state estimates that investments by these companies will exceed $527 million and will create almost 6,000 jobs. The continuing challenge is to develop growth in high tech industry broadly across the state. The state legislature recognizes the successful impact of MCNC through the upgraded education and research in microelectronics, through economic development, and through the national recognition of MCNC as a world-class facility, as is evidenced by the more than 2,000 visitors monthly.

The effectiveness of MCNC will also be measured in its capacity to develop rapid technology transfer mechanisms. In order to be successful in this regard, MCNC has structured its program to look like an industrial laboratory when seen by industry and more like a university when seen by the academic researchers.

NEW JERSEY COMMISSION ON SCIENCE AND TECHNOLOGY

The Governor's Commission on Science and Technology was established an initiative of the Higher Education Master Plan to increase New Jersey's role in the technology revolution. No other state has more scientists and engineers per capita. New Jersey spends more on R&D than any other state in pharmaceuticals and electronics, earning the reputation as the "laboratory of the nation." However, the contributions of growing industry in New Jersey are offset by a decline in employment in traditional manufacturing industries and New Jersey's recent decline in high technology employment.

The Governor's Commission was established in 1982 and was replaced by a permanent Commission in 1985. The permanent Commission is under the jurisdiction of the Department of Commerce rather than the Department of Higher Education because the initiative extends beyond the educational needs. The focus is on economic development and job creation, and not higher education per se, even though the greatest infusion of support will be made to higher education. Improvements in New Jersey's system of higher education are viewed as a primary factor in improved job generation in the state.

The Governor's Commission focused its work on four areas: academic-industrial innovation centers, capital for new technologies, technology-trained manpower, and improvement in the economic and regulatory climate. The Commission wanted to emphasize science and technology applications for new and traditional industries through new partnerships between graduate research, academic institutions, and industry; to increase the availability of capital to the state's businesses; and to promote economic development within the state.

A number of recommendations resulted from the Governor's Commission. Some of the key suggestions are listed below.

The state should establish the New Jersey Venture Capital Partnership to invest in new technology-based companies and the New Jersey Direct Placement Fund to make intermediate and long-term loans to ensure the growth of established technology-based companies in the state.

The State tax laws should be revised to allow businesses to carry forward losses from prior years and to encourage residents and corporations to invest in new, productive enterprises in New Jersey.

Regulations governing investments should also be changed to allow greater input into New Jersey-based companies and universities--providing "nurtured soil."

In addition to investment in enterprise, Governor Kean and the Commission promoted educational reform on all levels, which included providing excellent public school education by strengthening verbal, science, and mathematics skills and by providing appropriate curricula for gifted high school students. The Commission also recommended that the state improve the quality of higher education institutions in New Jersey by providing enrichment funding for a limited number of undergraduate programs to retain more of the state's top high school students; by creating a targeted funding program for support of undergraduate engineering and applied science programs; by improving the overall quality of graduate education in applied science, engineering, computer science, biotechnology, and related technical fields; by providing funds to upgrade instructional equipment and facilities in engineering and science education at both graduate and undergraduate institutions; and by developing systems for training and retraining the state workforce through apprenticeships and continuing education courses.

Based on the recommendations of the Commission, four complementary approaches are being followed to promote interaction between universities and industry: Business Incubation Facilities, Innovation Partnerships, Technology Extension Services, and Advanced Technology Centers.

The Commission recommended the establishment and operation of low cost business incubation facilities for start-up or early-stage companies with a single broadly defined technology. The recommendation, although not entirely established at this time, was to pattern use of the incubator after Pennsylvania's Incubator Program, particularly with regard to the close proximity to one or more institutions of higher education having potential academic and entrepreneurial services and shared access to computer facilities, laboratories, or other technical needs as appropriate.

Innovation partnerships have been established to aid academic scientists in commercializing their research. Matching research grants of $10,000 to $250,000 will be provided for applied research in emerging technologies of strategic importance to New Jersey's economy. Eligible applicants would be required to secure a conditional commitment of financial support from one or more companies. Matching grants may also be used to purchase equipment or to pay graduate student stipends. The grant applicant must be an academic, but a New Jersey company can identify an appropriate academic individual. The field of study must not be under investigation at one of the Advanced Technology Centers.

Technology Extension Centers are analogues to agricultural extension centers in bringing the latest advancements to the New Jersey industries for accelerated technology transfer. The centers are established in areas of technology where New Jersey does not have sufficient knowledge utilization, but where industrial capacity to receive this technology transfer does exist.

Of all of New Jersey's programs, the Advanced Technology Centers have received the most support and the most publicity thus far. Based on an 18-month analysis of New Jersey's academic and industrial strengths, several Advanced Technology Centers were created and reside in leading New Jersey institutions in fields such as hazardous and toxic substance management, materials science, food technology, telematics (communications and computer sciences), and biotechnology, and will be developed in other fields in the future. Funding for the centers is distributed through university treasuries.

Another outcome of the Commission's efforts is a $90 million Jobs, Science, and Technology Bond Issue to provide support for capital needs. The Bond Issue provides $57 million for Advanced Technology Centers, and $33 million to the Department of Higher Education for undergraduate technical and engineering facilities, for robotics and engineering training facilities, and for future needs.

The Commission has received funds totalling $16.075 million for the 1986 fiscal year. Funds for new and continuing programs constitute 97% of this budget, with administrative expenses held to 3%. The Commission currently projects industrial and federal matching funds to reach $26 million in FY86.

The Commission's matching guidelines currently require that each state-funded dollar for research and operations support of New Jersey's high technology initiative be equally matched by non-state sources (generally industry or the Federal government). Under the category of capital equipment, where corporate giving has been more conservative, the Commission requires that one-third of the total cost be represented in matching funds from non-state sources.

Program documents are validated through peer review panels. Program Funds have been requested for the Center for Ceramics Research, the Polymer Processing Technological Extension Center, the Center for Advanced Biotechnology and Medicine, the Cooperative Research Center for Hazardous Waste Management, the Center for Advanced Food Technology, the Center for Computer Aids to Industrial Productivity, and the Fisheries Development and Aquaculture Technology Extension Center. Innovation Partnerships are expected to exceed $2 million in FY86 including the fields of surface modification, biotechnology, and telematics. Funds for new programs have been requested for a program in fiber optic materials at the Center for Ceramics Research, the Plastics Recycling Research Program, the Information Services and Offices Automation Technological Extension Center, the Advanced Scientific Computer Center (Supercomputer), the American Electronics Association's (AEA) Challenge Grant, and the Small Businesses Assistance/New Venture Development Program.

The leveraging effect of industrial and state support is an important measure of the payback of New Jersey's investment in science and technology development. An indirect effect of the support will be the increase in the number of companies wanting to locate themselves near to the concentrations of research in New Jersey.

RENSSELAER POLYTECHNIC INSTITUTE INCUBATOR PROGRAM

The Incubator Program at RPI was formed as an "experiment" in 1980. Like Georgia Tech, RPI is an engineering school with a traditionally long-standing emphasis on applied science, engineering, and industrial service. RPI developed its Incubator Program for quite different reasons than Georgia Tech. It was conceived as part of its effort, Rensselaer 2000, under the guidance of then president George Low, to move from an undergraduate teaching institution to the forefront of international technical universities. The idea was to develop a high-technology research park that would draw leading edge technology firms to the area in order to attract top engineers as faculty to the upstate New York campus. Learning directly from the experience at Stanford, RPI administrators wanted to develop dynamic consulting opportunities by generating new firms.

A task force was formed to develop the technology park. This group suggested that RPI establish an Incubator Program to test, on a smaller scale, if the region could support high technology industries before the university invested in the technology park. The incubator came under the administration's purview, not under the academic purview of the university; the program was viewed primarily as a means to promote growth of high technology, an initiative broader than academic development. The Incubator Program has developed rapidly, in part due to the support of the Dean of the School of Engineering and the recognized notion that industrial interaction with the university is not a new concept.

In 5 years, the program has helped to "spawn" dozens of enterprises. Potential start-up firms apply to the program and are evaluated according to their likely success by Jerome Mahone, Director of the Incubator Program. Five percent of the applicants are admitted to the program. Sixteen companies are currently working in the facility.

RPI's literature emphasizes and promotes the positive impact of these start-up companies on both the local economy and the academic environment. Students use the new companies for part-time employment and for internships for academic credit. In effect, the Incubator Program provides a "living laboratory" for applied research. Faculty members consult with the firms, and some have started firms themselves. As for the new companies, they receive services and resources such as the use of libraries, data base systems, photocopying, laboratory facilities, and easy access to faculty consultants in technical, financial, and management areas. They also benefit from a sliding rent scale payment structure that reduces start-up costs. The university receives rent for the use of the office space and fees for the use of facilities, as well as a 2 percent equity interest in all companies except those started by its own faculty. There is no time limit for a company to remain in the incubator facility, but the sliding rent scale usually dictates how long a company will stay. As a private institution, RPI can accept stock from start-up firms in lieu of rent. It can also invest in companies, although university policy prohibits RPI from being the lead investor.

The Director believes that the Incubator Program as planned, has enhanced the public perception of RPI as a major technical institution. Small firms entering the program have not had the capital to buy space in the Research Technology Park, built in 1982 to house 15 high-technology firms, but start-ups are leasing space in the park. Nine of the 10 companies developed from the incubator have remained in the Troy area, indicating success in bolstering regional growth of high-technology, in having a positive impact on the local economy, and in increasing the attractiveness of RPI's academic environment.

As in the case with Georgia Tech, there has been little concern about proprietary rights or conflicts of interest. Faculty are encouraged and given incentives to take entrepreneurial roles. The only concern appears to be the possibility of subverting university overhead by channeling contracts through incubator firms. Proprietary issues are settled on a case-by-case basis.

The Program has broadened the university mandate so that it now views the Incubator and its start-up firms as relevant. The Incubator Program has been successful in meeting the goals for which it was established. It provides job training opportunities for students, consulting for faculty, and a source of potential future donors to the university and to the community. The Incubator Program increases local opportunities for faculty interaction with high technology firms, thereby increasing the attractiveness of RPI to faculty and students in a continuing effort to raise the caliber of the institution.

SEMICONDUCTOR RESEARCH CORPORATION

The Semiconductor Research Corporation (SRC) was established in 1982 as a non-profit consortium of U.S. companies united to strengthen the long-range generic research capabilities in semiconductor technology; to increase the supply of qualified personnel for the industry; and to disseminate information to its members for rapid technology transfer. The SRC was conceived as part of concerted national efforts to maintain international competitiveness in semiconductor research. The concerns in establishing SRC were to lessen fragmentation and duplication of research efforts and to train students for employment in industry.

There has been a general lack of understanding in the fundamental processes of manufacturing sciences and electronic packaging on the part of universities. SRC has undertaken to increase interdisciplinary research in these fields, primarily through electrical engineering departments, in order to redirect academic research and make it worthwhile for industry support. In general, SRC supports research for its creativity rather than for specific, short-term results.

The SRC's program strategy has gone through three phases. Phase 1 (1982-83) was to establish the initial program based on the perceived needs and university research capabilities. To sharpen the focus of the SRC, this initial phase was important in establishing themes, research vehicles, and an industrial mentor program. Phase 2 (1983-1984) was concerned with highlighting long-term industrial goals for semiconductor devices, developing industrial linkages and dissemination mechanisms, and establishing an effective program management system. Phase 3 (1984 and beyond) is geared toward sharpening the focus of program support to industry goals and toward expanding financial resources.

Thirty-five members currently belong to SRC. This membership base represents approximately 60 companies. It includes the top 5 U.S. semiconductor manufacturers and 20 of the top 100 industrial corporations. SRC membership fees are based on the individual firm's semiconductor activity and sales. The minimum membership fee for the calendar years 1985 and 1986 is $65,000 and the maximum is approximately $2.4 million.

SRC's Board of Directors is elected by the Semiconductor Industry Association and consists of executives from member companies. Two special advisory groups complement the board. The Technical Advisory Board has representation from each member company and provides a continuing industrial perspective on the research program. The University Advisory Committee, drawn from senior faculty of representative U.S. universities, provides advice on university relations, policies, and practices.

The Technical Advisory Board serves as the major focus of interaction and exchange among industry, university, and SRC staff. It reviews SRC research strategies and proposals, identifies industry research needs, develops dissemination mechanisms, develops the industrial mentors program, and reviews performance measurement criteria.

Ninety percent of membership dollars goes toward research conducted in universities and 10 percent toward SRC operations. The operating budget will increase in 1986 from $16 million to $19.4 million, among be allocated to research in microstructure, design, and manufacturing sciences. SRC has the final say in research conducted at the universities. The grant applications are reviewed in three stages: screening by SRC staff, evaluation by the Technical Advisory Board, and consultation by the SRC President and his senior staff.

SRC intends to set up Centers of Excellence in five different thrust areas. Currently three are in place at Cornell, Berkeley, and Carnegie-Mellon. SRC wants to reshape university research programs so that they will be attractive for industrial support and so industry will not immediately pull out its financial backing during difficult times.

Fifty-seven contracts are currently held at 37 universities. Over 50 percent of the total research budget has been awarded to six major universities in amounts as high as $1.7 million. The remainder of the funds range from $50,000 to $900,000. SRC is supporting research at a range of universities with the objective of enhancing the training of students to be recruited by a variety of types of companies.

SRC maintains extensive contact with its members through a monthly newsletter and other publications; through its Information Central computer system; through conferences, workshops, and short courses; through its Speaker Bureau (over 40 university researchers are under contract with SRC to give lectures at member companies); and through an extensive graduate student database.

There are a number of mechanisms where industrial members can actively participate in SRC. For instance, employees of member companies can hold faculty positions in participating universities. Under this program, employees stay in residence typically from 6 months to 2 years. Industrial Mentors are nominated employees of member companies assigned by SRC to guide university scientists in experimental fabrication and design. These mentors also serve the function of transmitting information back to the firm, thus promoting technology transfer. Currently, 145 mentors are affiliated with individual university research tasks. In addition to technical placements, managers from member companies can also be placed in residence at SRC sponsored universities for 1 to 2 years to provide an industrial perspective. Seven specialists from five member companies have participated to date.

Foreign companies are not permitted to participate in the SRC program. Foreign students, however, are permitted to work with SRC; these students generally decide to remain in the U.S. where opportunities may be better in manufacturing science. Therefore generally they are not viewed as a threat to industrial competitiveness.

Because of the generic nature of the research supported by SRC, intellectual property rights do not provide significant advantage to SRC members because such knowledge cannot be sufficiently protected through patents. In general, the university holds the rights to research, and SRC members have access to them on a royalty-free basis.

SRC has had a number of important impacts on semiconductor research. It has assisted in attracting top notch faculty and students to the field and therefore has assisted in increasing the university base. Universities, in turn, have a much greater awareness of industrial needs. SRC currently supplies half of the national support for university research in silicon, and has promoted research with higher risk and longer range efforts. The results of the research endeavors of SRC are beginning to be transferred to its members. To date, over 700 publications have come out of the research, 10 conferences, a number of workshops and courses, and an extensive Speakers Bureau has been established. SRC has become a recognized "voice" for the integrated circuit industry.

UNIVERSITY TECHNOLOGY, INC.
Case Western Reserve University

University Technology, Inc. (UTI), a non-profit subsidiary of Case Western Reserve University, is responsible for the commercialization of all campus technologies. Initially, UTI had been conceived as a for-profit program with pay incentives. Because of a change in the tax laws, however, incentives can be provided without the loss of non-profit status.

Case Western Reserve wanted to experiment with marketing and packaging university technologies through UTI. Numerous organizations are involved in licensing university technologies, but Case Western Reserve wanted to develop rapid transfer of potential products on a local basis with regional as well as university involvement. UTI is owned by the university, although it stands outside its purview. When it becomes fully incorporated, UTI is to be governed by an independent Board of Directors, selected by the university, but will have few, if any, university representatives.

Initial operations at UTI were supported by seed money of $300,000 from other operations at Case Western Reserve. The firm hopes to be self-sufficient in 5 years operating on a $200,000 annual budget. UTI will be located in one of the state's Incubator Program facilities which is owned by the university.

UTI will provide a "channel of intellectual excitement and creativity" through which faculty can see the results of their research brought to application. Such results will also facilitate the use of publicly funded research for public benefit, strengthen the vitality of business and industry in the region, and provide new intellectual stimulation, research, and student opportunities that marketing technology creates. Companies are chosen for start-up and production based on their perceived ability to rapidly develop faculty ideas into commercial products.

UTI will work in conjunction with the Office of Research Administration under the University Technology Application Program to identify, evaluate, and implement development strategies for potential technologies. The Office of Research Administration will initiate the commercialization process by performing preliminary screenings and registering new clients. Clients that pass the screen will be sent to UTI for a more rigorous, in-depth evaluation to ascertain commercial potential and the stage of technological development.

Technologies that are not adequately developed will be referred back to the Office of Research Administration for assistance in further development (e.g. obtaining federal funds). Projects not ready for commercialization, but developed sufficiently for recognition of the commercial potential will require an intermediate step with UTI assistance. This step may include acquiring seed capital or R&D capital, refining commercial strategy, etc.

UTI will create a commercialization strategy for technologies that are developed and ready for implementation including: developing intellectual property, protection, and patent strategy; defining the business and marketing opportunity; designing a business structure; and forming business, commercial, and financial relationships. Commercialization will ultimately result in a licensing agreement, joint venture, new company start-up, or some combination of these techniques.

The most common path to commercialization is by licensing proprietary rights to a company prepared to invest in further on-campus research and development of the technology. Typically, Case Western Reserve owns the title to patents and proprietary information. The university provides a royalty-bearing exclusive license in a specified field that matches the sponsor's capabilities and area of commitment for active development. Contracts will have a clause for reclaiming the license if the patent is not developed. The company organizes manufacturing and development markets for the products and submits semiannual reports to Case Western Reserve of all sales of devices on which the royalty agreement is based.

When the company owns a patent, Case Western Reserve has royalty-free use of the technology for on-campus research and development. The university has a 50:50 split distribution policy of net income--royalties and other rewards--to the university an to the faculty inventor. The university's income from royalties provides income for departments and schools and are currently used for the university's "Research Initiation Grants" which provide support for new faculty or senior researchers seeking to branch into new areas. Long-range royalty and equity payments are preferred; the university benefits only if the technology is a commercial success. A key goal is to construct agreements which are based on trust and respect, and which create a mutual desire to work together again.

It is unlikely that licensing will ever be more than a break-even proposition for Case Western Reserve, but the UTI provides the enormous benefit of increasing the volume of research measurably. The university has been actively licensing technologies for the last 2 years with more than 30 agreements in place. These agreements have already brought in more than $1 million of accompanying annual support for research over the next 3 years, and a fair fraction should bring royalty rewards within 5 years. The UTI has three start-up ventures in place and has several more in the "talking stage." About five patents are currently pending and another eight good patents have been acquired thus far.

Delay of publication is variable. The sponsor will have a short delay time (generally 30 days) to request a variable long-term extension for patent application or for stopping inadvertent disclosure of proprietary information. The university will go to its "best efforts" of maintaining confidentiality and of avoiding disclosure of proprietary information, while trying to minimize the university's obligations for confidentiality of results.

Faculty members are not prohibited from having equity interests in companies developing university technologies. However, faculty must not influence the university to provide a special advantage to a company in which they have an interest. Department Chairmen, Division Heads, Deans, and other faculty in leadership and supervisory positions are not permitted to have leadership positions in a company commercializing their research.

In addition to university support through the UTI, Case Western Reserve also undertakes targeted research. In the past, this industrial support accounted for about three to four percent of the university's total research budget. Currently that figure is over 5 percent. Targeted research support has increased because companies have had to diversify and cannot afford to broaden in-house potential. There is concern, however, that companies involved in the generic research centers at Case Western Reserve may see a greater advantage in supporting targeted research than basic research. In general, smaller companies have been more involved, in part because of their ability to adapt to academic concerns and their less rigid approach to change than some of the very large companies. University policy for conducting targeted research includes a clause stating that if students are not permitted to be involved in a project, the university will not undertake the research.

In addition to assistance in developing commercialization strategies, UTI is involved in other support service including: educating the campus community in opportunities and problems of technology transfer; publicizing the UTI application program to the campus and Cleveland communities; and assembling a database of resources for technology transfer.

Thomas Moss, Dean of Graduate Studies and Research and Interim President of UTI attributes its success to "facilitative marketing and serendipitous management." Customers have come to Case Western Reserve to ask to enter agreements which then only need to be facilitated. In addition, technology to date has largely been packaged and managed with informal advice of outside friends and alumni and "sometimes with fortuitous instincts."

Moss describes the support of the faculty as "some of the faculty, some of the time." This phrase is meant to take into account the heterogeneous nature of the faculty body within the university, the various individual approaches to research, and even the varying perspectives of a given faculty member at different stages of his research. Case Western Reserve has found that a number of faculty members are enthusiastic about the program, and this group appears to grow as the UTI and other programs expand in their capabilities.

By establishing workable guidelines within the context of the university, Case Western Reserve has been able to avoid conflict concerning UTI. The university has a strong tradition of industry-university cooperation which it accepts as a legitimate university activity that can mesh well with the basic goals of teaching and scholarship.

THE WASHINGTON UNIVERSITY-MONSANTO BIOMEDICAL RESEARCH PROGRAM

The research agreement between Washington University Medical School and Monsanto is an interesting example of a one-on-one relationship between a single company and a university medical school. It is particularly interesting because of the proximity of the two institutions. Less than 15 minutes apart, there is more day-to-day interaction, both at the working and the administrative levels, than in most alliances. The technology can be transferred by actually "hand-carrying" information from one institution to the other to close the gap between basic research carried out at the university and product development to be carried out at Monsanto. Indeed, proximity is what gives this program a somewhat unique character.

Historically, no overlap of research purposes had existed between the Washington University Medical School and Monsanto, so no previous collaborations had been sought. Monsanto decided they wanted to become a significant factor in the health care industry, but had no existing in-house group in biomedical research. In addition to the economic value of the program, scientists at Washington University were interested in seeing development of their applicable ideas.

The contract, signed in 1982, is at the institutional level and names no single investigator. This differs from a Monsanto-supported center at Harvard which was organized mainly around the laboratories of two cancer researchers.

The terms of the Washington University agreement reflected 5 months of negotiation by a small group of senior scientists from the Medical School and Monsanto executives. Their initial meetings were followed by an informal retreat at which about 20 scientists from each sector came together to discuss common research interests. The catalyst from the corporate side was Howard Schneiderman, who was familiar with the university environment from his own academic career. The vision, persistence, and perspective of Schneiderman and David Kipnis, Chairman of the Department of Medicine and Director of the Program, were critical in shaping the program.

The Monsanto contract is for \$23.5 million (in 1982 dollars) allocated over 5 years. The grant has expanded so that by 1987, support will be \$8.7 million annually. The research is in a broad but relatively well-defined subject--the proteins and peptides regulating cellular communication and function. The research is of commercial interest because of the potential for development of therapeutic drugs. Thus, the agreement was to support two kinds of research: 30 percent funds exploratory or basic research, and 70 percent supports more applied "specialty projects" focusing on specific proteins and peptides that could result in the development of products. Washington University owns patents accruing from research, but Monsanto has the right of first refusal to develop products under an exclusive licensing agreement.

The basic function of the program is to allocate research funds. This is undertaken by an internal review committee of five Washington University and five Monsanto participants--originally four and four until 1985. This committee evaluates grant applications from scientists at the medical school. The participants see this structure as modeled after the NIH granting process. Indeed, the committee is called a "study section," using the same name as an NIH review panel.

The fact that half of the review committee comes from the company gives Monsanto potential veto power over individual projects. In practice, however, alignments on the committee have reflected disciplinary and substantive interests (e.g. pharmacology) rather than place of work.

The whole program is to be reviewed every 2 years by a committee consisting of at least four outside scientists. The project is renewable on the basis of this review. Two years of advance warning is required before either side can terminate the contract.

Scientists involved in the Washington University-Monsanto Program have often expressed their visions and also their concerns when called on to testify before the House Committee on Science and Technology, and in other forums discussing industry-university relationships,

For Monsanto, the collaboration provides a means to have contact with research which might lead to novel and commercially attractive products that address human disease. The program serves as a "window" on research. Monsanto scientists pursue leads from the research for future in-house product development with the assistance of scientific expertise from the academic community. The collaborative effort provides more than simply hiring scientists in-house to conduct biomedical research. The arrangement forces Monsanto to take a much longer-term perspective of research application, to have "an increased half-life of faith."

Corporate administrators feel that the program has benefited them by stimulating their own scientists in more concrete ways as well, evidenced in publications and patent applications.

For the university, the collaboration provides a means to strengthen its own research capabilities. It allows scientists to move more rapidly into new research areas than might be possible under the cumbersome review procedures of NIH, it provides funds for innovative young investigators who have not yet established their reputation; and it encourages scientific entrepreneurship in risky areas that may or may not lead to development.

The program functions mainly as a granting service. It sends out requests for proposals to the entire medical school faculty. Each year to date, the committee has reviewed about 20 applications and approved six to nine grants for periods ranging from 18 months to 3 years at support from $40,000 to $400,000 per year. In early 1985, 30 investigators were being supported: 18 full professors, 8 associate professors, and 12 assistant professors. In each case, they work with Monsanto's scientists, often coauthoring papers. A Monsanto project scientist is assigned to act as the primary contact with each university investigator to expedite the transfer of information.

The most striking characteristic of the program is the close relationship between company and university scientists. Dozens of Monsanto scientists are involved in the research. University scientists also use Monsanto facilities and expertise in certain chemical fields and in molecular biology. Monthly seminars are held alternately at the university and at Monsanto. Annual retreats include scientists from both institutions and encourage easy interaction.

One project which has already been a successful outcome of the collaboration concerns research on atrial peptides. The first joint publication was submitted 5 months after the proposal received funding. Several more collaborative publications have followed.

All involved assume that there will be sufficient projects on which they can agree, so that no problem exists in arriving at a consensus as to which projects the review committee should support. Kipnis has remarked on the sensitivity of Monsanto scientists to academic norms that allow the close collaboration to work. The university does not perceive a situation where Monsanto will be able to dictate what research is being done at the university; the intention is to keep Monsanto's support of research at less than 7 percent of the total medical school budget. This limits the university's dependence on a particular project. In addition, the public nature of the program allows public scrutiny which may serve, therefore, as a safeguard for the integrity of the collaboration.

Monsanto has taken measures to protect its own interests in the collaboration. The Program Director submits reports to Monsanto on all important results as soon as they are available. Faculty may publish results, but they submit preprints to the Program Director and a Monsanto member of the advisory committee at least one month prior to submission for publication. Disputes over delays would be resolved by the Advisory Committee, but none have occurred to date. All participants in the research (students and faculty alike) must sign confidentiality agreements to protect any information that is corporate property. Scientists working on the project must also reveal their consulting arrangements to avoid conflicts of interest. Presumably, they are not to use the information learned from Monsanto in consulting for competitive firms. The company supplies the legal support for patent applications. Patentable results cannot be distributed broadly until Monsanto has evaluated their patentability.

The university has developed measures to avoid conflicts of interest and to safeguard academic norms such as open communication of scientific information. If a project/patent is successful, Washington University apportions royalties in the same way that it apportions clinical fees: 20 percent to the medical school, 40 percent to the department, and 40 percent to the principal investigator's laboratory to support further research and training.

Individual scientists do not make a personal profit. This provision was established in order to protect academic priorities and to assure that commercial ambitions will not take precedence over scientific motivations. This restriction works in the medical school context because of the precedent established for appropriating clinical fees, and the fact that salaries are negotiated accordingly. It is less likely to work in universities, which are often under pressure to provide financial incentives in order to keep their faculty from going to better-paid industrial jobs.

The university also seeks to avoid proprietary secrecy. Monsanto reviews papers resulting from the research prior to publication, but only for potentially patentable material. It can hold a document for 30 days. There are no blanket prohibitions against participating scientists holding stock in Monsanto, but they are supposed to disclose their holdings. The idea is that public disclosure, along with discouragement of personal entrepreneurial efforts connected with the research, will protect academic norms.

The project is conceived as a genuinely collaborative partnership. Schneiderman refers to himself as a "marriage broker" between two cultures with similar goals. Both the university and the industry seek to develop health care products for society; both want to enhance their scientific ability to develop innovative products through "basic" and "specialty" research; and both are concerned with the local economy in the St. Louis area. The emphasis is on consensus.

SECTION B: DESCRIPTIONS OF UNIVERSITY-INDUSTRY PROGRAMS BASED ON AVAILABLE LITERATURE

THE CENTER FOR BIOTECHNOLOGY RESEARCH/ENGENICS INC.

The Center for Biotechnology Research and its associated organization, Engenics, Inc., were established in 1981 to provide innovative and cost-effective processes for making, purifying, and using a wide range of biologically derived materials. Basic research is undertaken at Center-supported universities, and technology is then transferred to the Center and its industrial sponsors. The concept of having both universities and industry working as partners toward this goal, was to allow each phase to be carried out in the environment most likely to produce success. The profits of the collaboration will be shared with all of the participants as an incentive for interaction. The partnership is made up of four constituents: the universities, the industrial sponsors, the Center for Biotechnology Research, and Engenics.

The Center for Biotechnology Research, a non-profit corporation, supports basic research at universities, disseminates research results to the public, and facilitates the conversion of basic knowledge to product/process by industry. It is supported on a multi-year basis, by six sponsors: Bendix, Elf Technologies (a subsidiary of Societe Nationale Elf Aquitaine), General Foods, Kopvenco (a subsidiary of Koppers Co., Inc.), Mead, and Noranda. Funds from the sponsors are channeled to the Center through Engenics. Support for basic research through the Center was $2.4 million for the first 4 years.

Proposals for research are submitted to the Board of Trustees of the Center. More than 30 Ph.D. candidates have been trained through the Center over the last 4 years. In addition, 40 papers have been or are ready to be published, and 72 research presentations have been delivered. The Center currently provides funding for research on production and product separation processes at Stanford, Berkeley, and MIT. Any resulting patents will be held by the universities. The Center and Engenics will receive royalty-bearing licenses from the universities according to individual university policies. University researchers retain publishing rights.

Engenics is a for-profit corporation concerned with commercial development of biotechnology processes. Engenics undertakes both proprietary research and development activities, leading to joint ventures with partners, and contract bioprocess research and development services.

These are in four key areas: strain improvement, fermentation and bioreactor development, product purification, and process engineering.

The Governing Board of Engenics is composed of individuals with entrepreneurial experience and with technical and managerial backgrounds, and includes senior representatives of the sponsoring companies. In addition, a Board of Scientific Advisors to provides overall review and R&D guidance to Engenics.

The initial R&D objectives are to develop complete biological specific processes, with accompanying product separation and purification schemes that are efficient, reliable, and cost-effective for a variety of commercial products. The broad areas of focus will include: bioreactor design and development (continuous biosynthesis), separation process development, genetic engineering and cell line development, and analytical and control instrumentation development.

Engenics and sponsoring corporations share rights of first refusal on development of technologies or innovations that are conceived in university projects funded by the Center. Sponsoring companies receive options to purchase licenses to patents developed at universities under programs funded by the Center.

Quarterly reports and annual conferences sponsored by the Center create the opportunity for the sponsors to learn about key technological developments, and although it has no say in running the program, the Sponsors Advisory Committee keeps the sponsors informed about basic research programs at the universities and changes in proposals. In addition, sponsors have access to the faculty and students funded by the Center through employee "research sabbaticals" in university laboratories and student research conducted in sponsors' laboratories. The sponsors, therefore, have a "window" on developments in biotechnology research without having to increase their in-house staffing.

Engenics has issued 30 percent of its equity to the Center in exchange for the option to license university patents. The Center's profits from sublicensing income and appreciation of its share in Engenics are funneled back into research at the universities as a means to provide the universities a share in the financial success of the collaborative effort. It is hoped that this arrangement will free university researchers from the conflict-of-interest dilemmas associated with marketing patents and proprietary rights.

Each sponsor initially purchased a portion of the initial equity of Engenics and can maintain its proportional equity in any future financing. Thirty-five percent of the initial equity is owned by the sponsoring corporations at a cost of $7.5 million. The remaining 35 percent is held by the founders and key professional people at Engenics. Profits from patents as well as financial growth of Engenics will be divided accordingly. Research supported by the Center has resulted in four patents, six patent applications in the U.S., and a number of foreign applications.

CENTER FOR INTEGRATED SYSTEMS
Stanford University

The Center for Integrated Systems (CIS) was organized in 1983 to be, in the words of Stanford University president Donald Kennedy, "a social experiment" to investigate ways to organize efficient industry-university cooperation that will break down unnecessary duplication and secrecy. The Center brings together scientists and engineers from different disciplines for research on the development of very large-scale integrated systems with the aim of promptly transferring new technologies to industry.

The Center is funded by 20 sponsoring companies who have contributed a total of $15 million for a new building (to be completed in 1985); each company also has pledged $350,000 each over a 3-year period to support research and teaching. Most of the research, however, will be funded by government grants. In total, CIS has more than $40 million in support for facilities and research for the first 3 years. Located in the Engineering School, the Center represents over one-third of Stanford's total expenditures in electrical and computer science research. CIS involves about 80 faculty members (two-thirds of the total who work in related areas at Stanford), 150 research and technical staff members, and 300 graduate students. The plan is to train about 100 Masters and 30 Ph.D. candidates annually to be a new genus of intergrated systems engineers.

Stanford's motivation in taking these funds include the opportunity to remain at the forefront of research in a vital area that is closely linked to application. The goals of the industries include early access to students and to research in a highly competitive area. The sponsoring industries note that the intense competition from Japanese research efforts has encouraged this remarkable degree of cooperation among competing U.S. firms. John Young, president of Hewlett-Packard, and one of the main persons responsible for establishing CIS, suggests that the Center also provides companies with a chance to influence the direction of research. Finally, CIS is seen as a means of increasing the pool of students who are available for industrial jobs and of facilitating industrial recruiting.

The Center's policies are determined by the CIS Executive Committee, representing the interests of faculty members, and by the Sponsors Advisory Committee comprised of one representative from each of the 20 sponsoring companies. Delegation of formal responsibility is not stated in the literature. Rather, it stresses consensus and partnership.

The work at the CIS will be executed by autonomous project teams run by faculty principal investigators and will involve industrial fellows. Each sponsor is invited to assign a staff scientist to work full-time on the projects. All the projects will share the central facilities; proximity is expected to enhance collaboration.

The Center not only brings together scientists from several disciplines, but also fosters the mingling of employees from competing companies. This unique aspect of the CIS has raised difficult questions about intellectual property policies. Initial efforts by corporate and university lawyers failed to resolve differences regarding company deviants for exclusive rights, particularly concerning work involving their own employees. This problem was eventually resolved by a plan to categorize patents according to the inventor's employer's. Inventors on the Stanford faculty are subject to Stanford's patent regulations, which allow inventors to keep the patents and control the licenses for their work unless it involves government funds. If government funds are involved, the patent must be made available openly to bids for licensing; the Center's sponsors must bid competitively with firms not participating in CIS. A Patent Advisory Council was established to deal with problems arising from this format. Beyond concerns about intellectual property, university representatives assume that secrecy will not be a problem and expect that work will be disseminated via the normal practice of open publication, a newsletter, seminars, and educational tapes.

The chairman of the Sponsors Advisory Committee has dismissed the potential for problems claiming that the work is of such a basic nature that few, if any, patents were likely to result in direct application and that ideas with commercial application are more likely to be pursued in industrial labs.

CENTER FOR IRON AND STEELMAKING RESEARCH
Carnegie-Mellon University

The Center for Iron and Steelmaking Research was established at Carnegie-Mellon University in 1984 to develop a University/Industry Cooperative Center for carrying out basic research and for accelerating the transfer of basic research for use in new processes and technologies in order to keep the American steel industry competitive. The Center has two main purposes: to promote relevant research in iron and steelmaking and to train students for industrial research positions. CMU is an ideal site for such a Center because of the university's tradition in steelmaking research, its location in the heart of the steel industry, and its excellent faculty resources in a number of departments including Civil, Chemical, Electrical, and Metallurgical Engineering, Materials Science, the Mellon Institute, and the Robotics Institute.

Research projects focus on: the structural changes of iron ore pellets in the blast furnace and in direct reduction; kinematics resulting when solid particles are added to turbulent gas jets and plasmas; mathematical and physical modeling of mass transfer; inclusion, removal, and desulfurization in ladles; dephosphorization of Fe, Fe-Cr, and alloys by novel refining methods; mathematical modeling of horizontal casting; and magnetic confinement and shaping of steel in continuous casting operations.

Matching funds for operation of the Center are provided by NSF in declining amounts over the first 5 years. NSF provides guidance and expertise in the establishment of the Center as well. The anticipated annual budget for 1986 is $451,000; NSF will support CISR for $125,000, the Ben Franklin Partnership Program of Pennsylvania will contribute $46,000, and member companies will provide support in the amount of $280,000. In addition, a special equipment grant from CMU for $45,000 has been granted for a 75KW Induction Furnace.

Currently, 14 companies are members of the Center, a large number of which are located in Pennsylvania. Companies have two mechanisms for participating in the Center: iron and steel producers can join for $97,500 over 3 years and companies with limited facilities (e.g., only iron making, only steelmaking, and only suppliers to the steel industry) can participate for $41,000 over 3 years.

Industrial members receive a number of benefits through their association with CISR. They are exposed to research from a number of disciplines; they have leveraged their research funds through the matching NSF grants; and they have personal contact with excellent graduate students and post-doctorate researchers. Member companies have a number of means for interaction at the Center including semi-annual progress reports and project presentations at the Center's annual meeting.

Companies have 30 days to review manuscripts. They can request a delay in publication for up to 1 year for patent application and other reasons. The Industrial Advisory Board decides if a delay is warranted. The Industrial Advisory Board consists of one representative from each member company and a non-voting representative from NSF. The board meets at least twice a year to review proposals, advise the Center on research goals, appoint research monitors, and amend the Center's by-laws as necessary.

Patents belong to CMU, but all organizations may have a royalty-free license agreement if requested. Inventions made with NSF support are governed by the provisions of Public Law 96-517 affecting government-sponsored research. All computer software developed at the Center will be owned by CMU. Licensing of software for non-marketing or internal purposes will be royalty-free to member companies.

CENTOCOR, INC.

Centocor was formed in 1979 to develop innovative products for the health care market and distribute these products initially through existing channels. The company identifies commercial opportunities for health care which can improve patients' prognosis and/or quality of life. Hubert Schoemaker, president of Centocor, recognizes that the fundamental discoveries in biotechnology will come from the university sector and that Centocor can capitalize on these developments where "breakthrough technology spurs medical progress."

Centocor's niche is technology transfer. It recognizes technology developments at a very early stage before all market implications of the possible products are apparent, but is very market-oriented. Essentially, it commercializes university research. Centocor concentrates its in-house research on areas with the greatest medical need and where hybridoma technology can provide distinct technical advantages over present technology. Its primary efforts include research on cancer, cardiovascular disease, diseases of the immune system, and some infectious diseases. Three basic product lines are developed: blood tests, entire imaging products, and monoclonal antibodies for therapeutic use.

Centocor establishes collaborations with university investigators conducting basic research with potential for technological development. Centocor identifies a promising new development, defines the commercial opportunities, identifies leading research institutions and investigators and tries to establish collaborative agreements with these groups. Centocor will provide funds for follow-on research by these scientists to bring technology inside Centocor for product development purposes.

About 70 scientists are in the internal research and development group. Approximately half of their time is devoted to product development, including initiating clinical trials. Currently Centocor has at least seven products in clinical trials. Phase I of these trials was supported by a federal Small Business Innovation Research (SBIR) grant. Finally, Centocor secures appropriate approvals to market products. The marketing group is involved in opportunities, strategic planning, program management, and business development.

Centocor usually pays royalties to universities for innovations developed there and Centocor receives worldwide exclusivity for a specific technology. Currently, licensing agreements exist with about 30 U.S.

universities and 10 universities abroad. Centocor relys on other companies to distribute Centocor products, usually interacting with more than one company for distribution within a particular territory, to promote competition and maintain Centocor's control.

A number of products have been successfully developed through Centocor. At least five products have been patented and introduced including a Hepatitis B test. The company continues to grow in financial security which is relatively unusual for small biotechnology companies.

THE CORNELL UNIVERSITY BIOTECHNOLOGY PROGRAM

Cornell University is a major research university and a land grant college with a long tradition of community outreach, especially to agriculturally-based industry. Extension services are provided in the Colleges of Agriculture, Industrial and Labor Relations, and Human Ecology. A cooperative program in the College of Engineering also has extensive industrial ties. As of 1982, 250 faculty received support from 140 companies totalling $7 million. The university's contacts with industry have recently expanded through its supercomputer program and its Biotechnology Program.

The Cornell Biotechnology Program, established in 1982, includes two administrative units, the Biotechnology Institute and the New York State Center for Biotechnology. The Institute is a collaboration between Cornell and three corporations: Eastman Kodak, General Foods, and Union Carbide. Together these three sponsors providing $7.5 million over six years to support the Institute. (In addition, Corning, which had planned to be a member but reversed its decision with a change in management, contributed $450,000 to the Institute, and is a partial member for a limited period.) As part of a state-wide project to encourage Centers for Advanced Technology, the Center receives $1 million annually from the state to work on biotechnology in agriculture. Except for details regarding the allocation of money to specific projects, the Institute and the Center are administered as one program. Cornell provides some support by collecting less than its normal share of the indirect costs of sponsored research, and no faculty salaries are paid from program funds.

The Program awards grants for investigator-initiated research, for new faculty members to help set up their laboratories, for research facilities, for symposia and guest lecturers, and for publication of a newsletter with a circulation of 700. A new building will bring together scientists conducting biotechnology research, who are presently dispersed around the campus. As a service to New York state industries, the program provides a computer data base of Cornell scientists in related fields and describes their research. It also provides consulting to corporate sponsors and a base for visiting scientists from these firms.

In 1981, several scientists from the Department of Plant Science sought support from Kodak for a specific biotechnology research project. Kodak, at the time, was looking for a broader arrangement with the university, and Donald Cooke, Vice President for Research, brought together 35 faculty to discuss the possibility of an Institute. Along with the Director of the Division of Biological Sciences (now Provost) and the Director of Research at the College of Agriculture, Cooke wrote up a plan and a charter, and presented it to the Faculty Council of Representatives in the spring of 1982. The original plan was to solicit five industries to contribute $8 million each over 5 years. The faculty expressed concern about limiting the corporate membership to five sponsors, who might gain too close an association with the research, and the charter was expanded to allow for an unspecified number of companies. In fact, only three companies materialized, with a total contribution of $2.4 million over 6 years. Cornell applied for the state-sponsored part of the program after the corporate-sponsored Institute was established. Even at the less than anticipated budget, the Biotechnology Program is the largest privately-sponsored research project on campus except for the more recent supercomputer contract.

For Cornell, the Program serves as a lure for scientists in a competitive field and as a way to keep its "stars" at home. (It had previously lost a well-known scientist to the Whitehead Institute.) The Director, Gordon Hammes, also emphasized its importance to Cornell's "world image," and its interest, shared with industry and the state, in economic development.

For the industrial sponsors, the Program provides "know-how" in interesting areas of research well before publication and it provides access to sophisticated resources. Through the Institute, participating companies can explore new areas for future development without making long-term commitments. The three participating companies are all weak in biotechnology research. At present, Union Carbide does no work in biotechnology, but wants to decide whether or not to enter the field. Kodak does minimal research in related fields, but no pioneering research. According to Roy Snoke, Kodak's visiting scientist in the Program, company executives believe that Kodak's relationship with Cornell will bring the company to the "leading edge" of biotechnology. They have a say in establishing research directions, gain opportunities to recruit consultants and research staff, and have access to opportunities to train industrial personnel. Representatives from the industries involved made it clear, however, that they do not wish to direct or change the university's research.

The state's interest, expressed through the activities of its Committee for Economic Development, lies in the potential benefits for New

York's economy. This committee has six members from the state government, one or two members from each corporate sponsor, and eight Cornell faculty. Its role is to explore the potential economic benefits of biotechnology for the state and to serve as a means for state influence on the Program. The state has tried to increase the emphasis on applied research, although the industrial sponsors recognized the merit of basic research. Both Cornell and industry participants are wary of the state's interests in emphasizing application.

Cornell was extremely careful to set up administrative arrangements that would keep control of the program within the Cornell scientific community. Even so, the plan was "viewed as an experiment," to be altered should circumstances change. The Executive Board develops the strategies and guides the overall thrust of the program. It consists of Cornell's Vice President for Research, the Deans of two of the participating colleges, the Director of the Program, the Director of the Division of Biological Sciences, one representative from each major corporate sponsor, the Chairman of the Economic Development Committee, two Cornell faculty members, and the Chairman of the Research Policy committee of the Faculty Council of Representatives. The Cornell presence is dominant.

Once a year, the Scientific Administrative Board decides which proposals to fund and helps to develop "the scientific exchange program." Its members are the Director of the Program, six Cornell faculty, and a representative from each corporate sponsor. A member of the Economic Development Committee, the Vice President for Research, and the Director of the Division of Biological Sciences sit on the Board without a vote.

Gordon Hammes, Director of the Biotechnology Program, is a faculty member in the Department of Chemistry. The Program pays 50 percent of his salary and 25 percent of the salary of one of his two Associate Directors.

The investigator-initiated grants provide a maximum of $50,000 per year for up to 2 years. This support is used primarily for salaries, supplies, and equipment. The proposals must be for new projects and are supposed to be collaborative among laboratories.

Because the program encourages innovative research, the grant proposals are far less detailed than typical NSF proposals. Three to four page letters explaining a new idea that seems worthy to research is sufficient. In the selection for 1985-86, 56 proposals were considered, 11 of which were requests for renewal. Nineteen projects were funded, including seven renewals. In addition, 13 projects entering their second year will continue to be funded. In all, the program will fund 32 investigator-initiated grants. The Program will also support eight new investigator grants and five research facilities.

The faculty interviewed were not concerned with who was supporting the Program and often did not know whether their grant came from the state, from industry, or from both. The interest lies more in developing basic knowledge, though in light of the interests of the state, some research emphasizes agricultural applications.

The new investigator grants are support for 2 years of about $25,000 for equipment, supplies, and personnel needed to set up a new laboratory. Two recipients of the new investigator awards stated that the presence of the Program affected their decision to come to Cornell. The Program also supplies visiting industrial scientists with supplies and equipment to carry on their research, although their salaries are paid by their corporations.

The two parts of the Biotechnology Program cater to different constituents. The Institute seeks to increase communication with corporate sponsors, while the Center encourages small biotechnology industries in the state. Thus, they have developed different means of communication. The Visiting Scientist Program is the major vehicle for disseminating information to the sponsoring industries. One scientist from each supporting firm is invited to spend an extended time at Cornell. Usually they focus on a particular field related to their industrial research, but come to Cornell to learn whatever they feel is interesting in biotechnology and to provide a liaison between Cornell scientists and their industrial colleagues. Roy Snoke from Kodak spent three to four months in each of several laboratories working with professors on particular projects. Snoke believes that industry has a responsibility to give more than money to this relationship. For example, he discovered that Kodak had invented a chemical for developing film that could also be used as dye for assays in Cornell biology laboratories. Several persons interviewed mentioned this episode as an example of how industrial research can help university research. Snoke lunches with several faculty members regularly to give them a clearer view of industry and to find out more about their own work. He alerts industry colleagues to seminars, key papers, and lectures at Cornell, and when possible, tries to arrange meetings between scientists at the two institutions. He is less well-acquainted with students though he has counseled some individuals about jobs. He also taught a mini-course about industrial research.

Union Carbide's scientist, Dean Bushey, describes his role as both a student attending classes and as a colleague bringing knowledge in his own specialty. According to Bushey, Union Carbide did not send a scientist the first year, and gained little from the research. The company now believes that the visiting scientists are essential to the Program. Bushey sends monthly reports about the research at Cornell back to Union Carbide for publication in a company journal.

The Committee for Economic Development carries out research in economics. Dr. Robert Kalter, professor in the Department of Agricultural Economics and member of this committee, says that it also acts as a "two-way conduit" between the university and local farmers and agricultural businesses. He believes that Cornell scientists "are looking for real-world problems" and can learn about what these problems are from the agricultural sector. Eventually, those involved hope to create a state extension program that will aid new corporations in getting started by directly giving them the resources that Cornell has to to offer.

The Economic Development Committee also studies the potential economic consequences of biotechnology research. For example, it wrote an influential paper and Congressional testimony on the effects of Bovine Growth Hormone in revolutionizing the milk industry. The study predicted that this technology would have a dramatic economic impact on agricultural production, land prices, and farm economics. It suggested that the dislocations could be profound and recommended that farm businesses optimize their management in terms of this technology if they are to succeed. Interestingly, this is the only instance we have come across where policy analysis is integrated into a scientific program.

The Program's first patent application was filed in the spring of 1985. Donald Cooke, the Vice President for Research during the Program's formation, emphasizes that the Program follows the university's policies for sponsored research. The patent work is handled through the University Patent Office, which has upgraded its legal services in order to cope with expanding patent questions. It has also upgraded its public relations office to meet the increasing concern about media image in an environment where research money is sought increasingly from corporate executives and state politicians, as well as through peer review. All patents filed through the Biotechnology Program belong to Cornell. The contributing industries receive non-exclusive, royalty-free licensing. Under the present arrangements, the inventor does not receive royalties, but this policy is being re-evaluated in order to provide greater incentive to file patents. The delay in seeking royalty-paying licenses from other than sponsors will be shortened. Industry is expected to accept this plan because their return is not necessarily represented by patents. At this time, they are more interested in access to new research than in short-term profits.

Emphasizing that the Institute mainly works on basic research, Hammes minimizes the importance of the patent question. Publication is the main goal. Twenty-five papers have been published through the program as of the spring of 1985. Preprints of all papers are sent to each industry. The industries can delay publication for up to 120 days if they believe the paper contains potentially patentable material, but they cannot prevent publication. None of the faculty interviewed felt that the delay would be an inconvenience. One of the grant recipients mentioned that the industry review was beneficial; when Union Carbide chemists reviewed his preprint, they helped him name a compound that he was using in his work.

The only complaint expressed by researchers is the short time frame of the grants. The short term of the funding, however, is deliberately intended as "seed money" to provide resources for germinating an idea until it can stand on its own to qualify for long-term support. The short time period of Program projects makes some professors reluctant to support graduate students because of uncertainty about long-term support, unless they had other sources of funding.

Students viewed the Program as just another source of money, though some felt that they would benefit by more interaction with potential industrial employers. Graduate students and post-doctorates are instrumental in the research because of its interdisciplinary nature. They are an important communication link between laboratories, often in different disciplines. Those faculty who seek renewals also apply for outside funding using the Program as a back-up.

The broader effect of this Program on the university is not yet understood, particularly in regard to the effect on hiring and research in the biological sciences and, more broadly, in the university. There is also some concern that these arrangements will effect the credibility of the university creating the image that it is working for specific private corporations rather than doing research available to all, proponents insist that research is open to all, yet they lure corporations with the promise that they will gain unique access to knowledge in commercially attractive fields.

DEPARTMENT OF MOLECULAR BIOLOGY
Massachusetts General Hospital/Hoechst

In 1980, Howard Goodman approached Hoechst with the concept of creating a molecular biology department with talented researchers who need not be concerned with financial aspects of research. Goodman had been a consultant for Hoechst, and so, was familiar with this firm prior to submitting the proposal. He has no stock or other personal financial interest in Hoechst, however. Hoechst saw the 1980's as a decade to focus on biology and was anxious to expand its pharmaceutical operations. The firm wanted a "window on science."

Initially, Goodman tried to set up the new department at the University of California at San Francisco, where he was a member of the faculty. However, constraints in dealing with the vast University of California system, as a public institution, created difficulties in the negotiation process.

Massachusetts General Hospital (MGH) had independently decided to establish a Department of Molecular Biology and began 'courting' Goodman. Eight months after Goodman first approached Hoechst, the company signed an agreement with MGH for $70 million over a 10 year period. Hoechst will provide a guaranteed minimum annual funding level that increases to $6 million per year in the last 7 years. Hoechst maintains the right to fund all additional research at the department. If the company does not exert this option, MGH may seek funding elsewhere provided the department does not accept funding from any other profit-making entity (without Hoechst's written consent). After the initial 10-year funding period, the agreement will be extended for additional 5-year increments unless either party requests termination by the end of the second year of each 5-year period.

Hoechst provides funding to MGH for basic research in a newly established Department of Molecular Biology. Research is focused on improved medical care using eukaryotic cell gene regulation, somatic cell genetics, microbial genetics, virology, immunology, and plant molecular biology. Research will be sponsored, but not directed, by Hoechst.

Initially, the Department was comprised of about 50 scientific and support employees. Staffing is expected to double. Like all MGH employees, investigators in the Department of Molecular Biology must sign a Participation Agreement administered by MGH's Office of Technology Administration. Under this Participation Agreement, employees agree to disclose inventions and to comply with procedures and policies on consultation and collaboration. Investigators in the Department are regarded as regular members of MGH staff; they are nominated for membership in the faculty of Harvard Medical School, and as appropriate, are recommended for tenure.

Hoechst can have up to four company scientists at any one time in the Department. The expectation is that these company scientists will return to Germany to head Hoechst's research laboratories. Time at MGH is therefore viewed as an important step in establishing a career at the company.

The Joint Committee consists of three members of MGH's Board of Trustees and three senior executives from Hoechst. This group oversees the implementation of the agreement and serves as a forum for communication between MGH and Hoechst.

Department employees need not write grants as part of the peer evaluation process. MGH and Hoechst are aware that the lack of peer feedback and the loss of the discipline of grant writing may be a disadvantage of the arrangement. To compensate, evaluation by the Scientific Advisory Board Committee has been instituted. Senior investigators will prepare individual annual reports on the progress of their research including reprints of all scientific articles published during the year. These reports will be incorporated into Goodman's annual report of the Department to Hoechst.

The Scientific Advisory Board also reviews the performance of the Department and makes recommendations concerning work and operations. If the objectives are not being met in a satisfactory fashion, MGH must take steps to correct the situation, although obligations regarding support and operations of the arrangement will remain intact.

In addition, the Advisory Board evaluates the Department's annual report, prepared by Goodman, which includes progress reports by all senior investigators in the Department. The Advisory Board is currently made up of six scientists: two affiliated with and appointed by Hoechst, two scientists affiliated with and appointed by MGH, and two unaffiliated scientists, jointly appointed.

At least once a year, the Department will hold a 2 to 3 day symposium for invited academic participants to discuss research conducted at the Department. Hoechst may send employees and other individuals to the symposium, but will give the Department notice of the numbers of those attending. In addition, Goodman will report directly to Hoechst representatives up to three times a year. Senior investigators will confer with company representatives at least once a year.

The agreement is unusual in that Hoechst provides funds of approximately $18 million for renovation of a temporary facility, and for construction and equipment for a new facility to house the department. Renovating the initial space and building the new facility are being carried out in such a way that no third party (including the U.S. government) will be able to acquire rights or equity in any work accomplished solely in the Department by personnel of the Department. All equipment purchased through the agreement becomes property of MGH. Equipment can be transferred out of the Department upon payment of the fair market value to Hoechst. The Department will occupy 4 of the approximately 10 floors in the new building, the Wellman Research Building. The building, to be completed September 1985, will to be named after Arthur and Gullan M. Wellman, who have pledged $15 million to MGH for construction with what is believed to be the largest single contribution ever to an existing U.S. hospital.

MGH will submit manuscript drafts to Hoechst at least 30 days prior to submission for publication. If MGH and Hoechst agree to apply for a patent, applications will be the property of MGH. In return, Hoechst receives an exclusive world-wide license. If Hoechst does not begin commercial development within 3 years after the date of filing patent application, then the license becomes non-exclusive. If Hoechst does not wish to file a particular application, MGH can file for patent rights or release them to the inventor under limitations of the agreement. If MGH is not interested in filing, Hoechst is free to file in its own name.

Hoechst will pay MGH royalties for any license granted. Rates will be established in consideration of Hoechst's support for the research and the amount of royalties being paid on other licenses by Hoechst, but will not exceed 50 percent of the fair commercial royalty rate. In the event that an agreement on rates cannot be reached, the matter will be submitted to arbitration according to procedures of the American Arbitration Association. Royalties will be allocated among the inventor, the Department, the inventor's laboratory, and the general research funds of MGH in varying percentages. Proportions will shift from the inventor to the MGH general research fund as the amount of royalties increase.

Royalty payments to the department are considered part of the total support guaranteed by Hoechst.

In research collaborations funded in part by Hoechst and in part by a third party, Hoechst's interest in obtaining exclusive world-wide licenses must be considered. Collaborations will entitle Hoechst to the most favorable license obtainable, at least a non-exclusive license. Arrangements will automatically take into account restrictions that the federal government may have in a collaboration.

The MGH Committee on Patents, which interprets and applies patent policy procedures for MGH, will oversee the Department's patent activity.

The Department received a great deal of public attention in 1980 because of the concern in establishing an alliance with a foreign partner. Apprehensions were expressed by the U.S. Government, and American and German institutions. The agreement has detailed consideration for patent policies, ownership, etc., in an effort to alleviate the concerns. Since the inception of the program, publicity and furor have subsided.

MAGNETICS TECHNOLOGY CENTER
Carnegie-Mellon University

The Magnetics Technology Center (MTC) was established at Carnegie-Mellon University in 1982 as an umbrella organization for magnetics research. Faculty and students undertake interdisciplinary research primarily in magnetic storage devices (magnetic bubbles, magnetic and magento-optic recording) but also in hard magnetic materials, finite element modeling, and fine particle interactions. The staff is composed of 24 faculty members from eight departments (Physics, Computer Science, Metallurgical Engineering and Materials Science, Mechanical Engineering, Mathematics, the Mellon Institute, Chemical Engineering, and Chemistry), 12 visiting researchers, 53 graduate students, and 3 technicians. MTC grants 10 Ph.D.s and 20 Master's degree students in magnetics technology every year.

Before formal formation of MTC, magnetics faculty at Carnegie-Mellon had contract support of approximately $1 million annually from NSF, the Air Force Office of Scientific Research, and industry to provide the research base and the students necessary to compete with Japan's efforts in magnetics technology. MTC was formed in 1983 and during the 1983-1984 academic year, support grew to more than $3 million. By the middle of the following year, annual funding had surpassed the $4 million goal of the Center's budget with support coming from DOD, NASA, NSF, the Air Force, and industry.

Money invested in MTC is used for direct support of research programs and equipment. Most of the funding is provided by companies with a large interest in magnetics technology, who support MTC as Associate Members in the amount of $750,000 each over 3 years (of non-earmarked funding). Organizations with limited resources or a narrower interest can make smaller commitments and receive a smaller package of benefits as Affiliate or Limited Members at $150,000 over 3 years. The interaction among the 20 member companies provides a unique situation where companies can share expenses without violating antitrust regulations. Members must acknowledge the work of the Center in any public reports citing research done at the Center.

Associate membership benefits include access to graduate students and faculty, preprints of research reported by the Center, an invitation to the annual members meeting and review of the MTC's program, the annual report of MTC's activities with research presentations, free use of computer software developed at MTC, royalty-free licenses to patents received by the Center, the right to place one research scientist/engineer in MTC, and membership on the Advisory Board. The Advisory Board is composed of a Chairman, appointed by the university, selected MTC faculty (with no voting status), and one voting representative from each Associate Member organization. This group provides guidance for future research activities.

Carnegie-Mellon provided support for building a new facility for MTC, including a class 100 clean room. The facility was completed in 1983. Faculty members maintain their own laboratories on the CMU campus, and have access to the NSF sponsored materials research laboratory, the Center for the study of Materials.

MTC offers a short course in magnetic and magneto-optical recording every 6 months at different universities and plans to interact more actively with other NSF Centers carrying out relevant research.

Most member companies request students for summer employment. MTC has provided at least one student to each requesting company. (Last summer, 12 students worked for sponsors.) Industrial sponsors often visit the Center. The Center has at least one company visitor per week.

In 2 years, MTC has virtually met its long-term goals with respect to funding levels and numbers of faculty and students involved. Government agencies funding for research at MTC is an unpredicted boon. Over 100 research papers have been published out of the Center and 20 students have been admitted for the next school year (12 are expected to attend). These students are top-ranking as judged by their grades, GRE scores, and recommendations. Some of the students have previously worked at member companies either for the summer or as full-time employees.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY/ EXXON RESEARCH AND ENGINEERING CO.

MIT has a long tradition of close association with industry and is unusual in its relatively high percentage of industrial support of research. MIT currently receives approximately 10 percent of its research funding from industrial sources. Excluding consortia support, almost all industrial funding at MIT is directed to relatively small projects with two major exceptions, the Exxon grant and the W.R. Grace Company grant.

The agreement between Exxon and MIT, established in 1980, provides research support on topics from combustion of carbonaceous fuels to high-temperature reactions associated with fossil-fuel conversion and utilization (combustion, gasification, and pyrolysis).

The Project Committee, consisting of two Exxon representatives and the MIT principal investigators, meets twice yearly to review ongoing projects and recommend appropriate changes; to review results and proposals; to make recommendations for new projects; to identify inventions and possible patentable materials/technologies; and to review MIT personnel in order to identify potential conflicts concerning patent rights and third party related research.

The Committee decides which research topics fund based on the potential scientific and technological contribution, the breadth of applicability, the relevance to long-term Exxon and national interests, and the potential for research interaction between MIT and Exxon. The decisions of the committee must be unanimous.

Currently, eight topics receive support from Exxon. Once a topic has been decided upon, Exxon must agree to support the project until the students conducting the research have graduated. The Principal Investigator is responsible for assigning appropriate MIT personnel to a given project. Exxon currently supports nine Ph.D. candidates, two Master's candidates (seven have received support), and, on average, 12 undergraduates at any one time. (The undergraduates are part of MIT's Undergraduate Research Opportunities Program, a university-wide effort to involve undergraduates in research.) Students have been stimulated in their work by the interest and exchange with Exxon researchers working on similar problems. In addition, Exxon researchers have enjoyed the exposure to students, particularly undergraduates.

Exxon provides MIT with $8 million allocated over 10 years. Either party may terminate the agreement by giving 2 years prior notice. Approximately 20 percent of Exxon's support is allotted as discretionary funds, typical of many MIT arrangements. MIT retains equipment purchased with Exxon funds.

MIT provides Exxon with quarterly progress reports and a final technical report at the end of each project. Exxon also is informed of all MIT and MIT/Exxon contract inventions.

MIT has a university-wide policy of outlining the rules of an arrangement prior to establishing the alliance. Guidelines established by the university include a prohibition against undertaking proprietary research. Under the agreement with Exxon, all research results may be freely disseminated and publications will acknowledge Exxon support. On occasion, however, it is useful for research groups at MIT to receive proprietary information concerning research conducted at the company. MIT has resolved this problem by allowing only the Principal Investigator to be privy to such information. This policy ensures that students can freely discuss their research. Recognizing that the Principal Investigator has received proprietary information, MIT permits a 30-day delay of publication to protect the sponsor from inadvertent disclosure of information. (Oral presentations by MIT personnel at professional meetings are treated like publications to the extent possible.) An additional 60-day extension can be granted to allow time for patent submission.

MIT personnel must sign written agreements with MIT with respect to inventions, patents, technical information, and publications. A similar provision is also in place for Exxon employees who perform joint research with MIT personnel.

Patents arising from Exxon-supported research are the property of MIT unless developed through joint research. In the latter case, the patents are held jointly by Exxon and MIT. MIT provides Exxon with worldwide, non-exclusive, royalty-free licenses for all patents without accounting to MIT. Exxon grants MIT an irrevocable, exclusive worldwide licensing right, which includes the right to grant non-exclusive and exclusive sublicenses to third parties, but will provide Exxon with copies of all sublicensing agreements. This licensing arrangement is one that has traditionally been successful for MIT. The university and Exxon will share royalty payments from sublicensing of MIT or MIT/Exxon contract patents. Because of the difficulty in determining how successful a patented material or technology may prove to be, the arrangement of royalty rates and license duration are typically left until after the patent has been issued, relying on good faith by both parties.

MIT provides Exxon with irrevocably worldwide, royal-free licenses, and with the right to license others on all copyright publications. MIT owns copyrighted publications covering inventions and technical information developed under contract with Exxon by MIT personnel. Joint title of copyrighted publications are held by MIT and Exxon for MIT/Exxon contract inventions and technical information.

The literature attributes the long-term viability of the MIT/Exxon arrangement to a commitment to stability, intellectual connections among the parties, industrial, respect of academic traditions, flexibility in the directions of research, and university sensitivity to Exxon's motivations. The Exxon/MIT partnership has policy guidelines that are specific and in many cases, come from university-wide policies. This fact is not surprising when one considers the charter of MIT, which indicates an expected association with industry from the university's inception in 1861.

NEOGEN CORPORATION

Neogen Corporation was established in 1981 with seed money from the Michigan State University Foundation to transfer technology from the university environment and to develop products for use in agriculture. Neogen is a market-driven company which uses biotechnology to develop new products. The company intends to develop and market products in protection and improved health care of animals, and diagnostics and instrumentation aimed at reducing disease loss and increasing the shelf-life of perishable crops. Neogen only undertakes research projects that it perceives can be brought to market within 3 years.

Neogen Corporation is organized into three subsidiaries: Neogen Food Tech, Neogen Biologies, and Ideal Instruments, Inc. The research conducted at these corporations is concerned with plant health, animal health, and veterinary instruments, respectively. In most cases, these subsidiaries will market and distribute Neogen's products, although in some instances, products may be distributed through existing, large scale corporations. Neogen will retain rights to manufacture the products in these cases.

Currently, Neogen supports research projects in its own laboratories in Lansing, Michigan and San Francisco, California, as well as sponsored research at Michigan State University, Auburn University, and the University of Tennessee. Research contracts are currently in the planning stages at six other universities. Neogen has committed approximately $3 million to support contract research.

The corporation recognizes the merit of supporting top researchers at universities, in addition to internal research. After identifying a specific need, the corporation searches for and contracts with the best research team for conducting R&D under Neogen's supervision. This mechanism speeds up the transfer of technology, reduces the risks involved, and minimizes the need to increase in-house staffing.

Directors and members of the Scientific Review Committee are experienced in scientific and industrial research, product development, and managerial and financial aspects of marketing new technologies. These executives make decisions on each product development activity with respect to scientific feasibility, scope, and potential of each market and future market possibilities. The MSU Foundation has expanded its support of Neogen programs and has become a principal investor. Other key investors include a major retirement fund, a venture fund specializing in agriculture and energy development, a bank holding company, and Michigan's largest venture capital firm.

Neogen is growing through acquisitions of small firms and through internal development in its subsidiaries. Ideal Instruments, Inc., acquired by Neogen in 1985, currently has a line of 150 veterinary products ranging in price from $3 to $3,000. In addition, Neogen Food Tech currently manufactures and distributes Seed and Ethylene Analyzers, in addition to distributing Ethylene Scrubbers, Water Core Testers, Flesh Firmness Testers, and other harvesting tools. Neogen will continue its current strategies based on its success in product development over the past few years, to aim for over $30 million in sales by 1990.

THE ROBOTICS INSTITUTE
Carnegie-Mellon University

The Robotics Institute of Carnegie-Mellon University was established in 1979 to engage in advanced research and development in two areas: automation and computer-integrated manufacturing and robotics in hazardous environments, for facilitating transfer of these technologies to industry. Factory automation research focuses on productivity and product quality problems of high risk and potentially high payoff. Hazardous environments research includes robots for use in undersea, space, nuclear reactor, and deep shaft mine environments.

The Institute is organized as an interdepartmental matrix consisting of 25 affiliated academic faculty members, 20 research scientists, 45 research engineers and programmers, and 60 graduate and undergraduate students. The research is currently carried out in 15 laboratories organized into eight primary groups.

During the 1985 fiscal year, the budget for the Institute exceeded $9 million. About 60 percent of these funds came from about 25 industrial sources. The remaining support came from federal sources. Companies can sponsor research at the Institute under one of three mechanisms. Primary Sponsors provide multi-year grants of $0.5 to $1 million annually for discrete, but related projects under broad programs. These companies may receive patent rights for technologies developed through their sponsorship. Associate Sponsors are members of a limited consortia supporting specific research programs at levels ranging from $65,000 to $250,000 annually. Associate Sponsors receive licenses for internal use of developed technologies. The third mechanism for sponsoring research, the Industrial Affiliates Program, was established at the Institute to broaden industrial support and participation. Industrial Affiliates provide renewable annual grants of from $10,000 to $50,000--depending on annual revenues--to support seed projects. Affiliates receive non-exclusive licenses for technologies developed from these projects. In the interest of manufacturing technologies developed at the Institute, sponsors receive all nonproprietary data and computer programs generated by the Institute on a royalty-free, non-exclusive basis. Sponsors also have a number of interactions for consulting, tutorial, and recruiting purposes.

The Robotics Institute follows university-wide property policy established in 1985. The policy requires that intellectual property ownership be specified at the outset of the agreement. The inventor of any patentable property must disclose the work to the Provost. Carnegie-Mellon owns patents for technologies developed by CMU employees who have been hired to work on the specific technologies. The inventor retains the rights on any materials developed for educational purposes and all property created without substantial use of university laboratories, equipment, and facilities, when not limited by other patent regulations.

Property created with substantial use of university facilities, but not arising directly from external or CMU sponsored research, the property is owned by the inventor. If the inventor fails to develop the technology, however, the property is acquired by CMU. The same holds true for property created from sponsored research for which ownership has not been specified.

Any disputes concerning ownership rights are submitted to the university's Intellectual Property Adjucation Committee which reviews the matter within 60 days. The committee consists of a Chairman, who is a tenured faculty member, four other members of the faculty, and four members representing the university administration, the technical staff, and the graduate and undergraduate student bodies. If any of the parties is not satisfied with the committee's decision, they may seek binding arbitration in Pittsburgh in accordance with the rules of the American Arbitration Association then in effect.

APPENDIX B

CONFERENCE AGENDA

Thursday, December 5, 1985

8:15 Registration, NAS Auditorium

8:45 Welcoming Remarks
FRANK PRESS, *President, National Academy of Sciences*
DALE R. CORSON, *Chairman, Government-University-Industry Research Roundtable*

9:00 Overview: Demystifying University-Industry Alliances
RICHARD R. NELSON, *Professor of Economics, Yale University*

9:30 Session 1: Goals and Expectations for University and Industry

-- Program Representatives Respond to Discussion Questions

DONALD S. BEILMAN
President
Microelectronics Center of North Carolina

MARVIN C. GUTHRIE
Director
Office of Technology Administration
Massachusetts General Hospital

JAMES F. MATHIS
Vice President for Science & Technology
Exxon (retired)

JAMES D. MEINDL
Co-Director
Center for Integrated Systems

-- Panel Response

10:45 Break

11:00 Discussion
Questions and Comments from the Audience

11:45 Lunch, NAS Refectory

12:45 Session 2: University Culture and Commercial Values

-- Program Representatives Respond to Discussion Questions

ANGEL G. JORDAN
Provost
Carnegie-Mellon University

FRANKLIN A. LINDSAY
Founder of Engenics and
Former President and Chairman
Itek Corporation

JAMES L. HERBERT
President
Neogen Corporation

THOMAS STELSON
Vice President for Research
Georgia Institute of Technology

-- *Panel Response*

2:15 Discussion

Questions and Comments from the Audience

3:00 Break

3:15 Session 3: Technology Utilization, Innovation, and Economic Development

-- Program Representatives Respond to Discussion Questions

GORDON HAMMES
Professor of Chemistry
Cornell University

WALTER H. PLOSILA
Deputy Secretary for Technology & Policy
Ben Franklin Partnership Program
Pennsylvania

THOMAS H. MOSS
Dean of Graduate Studies & Research
Case Western Reserve University

HUBERT J.P. SCHOEMAKER
President
Centocor, Inc.

-- Panel Response

4:30 Discussion

Questions and Comments from the Audience

5:15 Summing Up: Initial Observations on the Impacts and Effectiveness of the Alliances

Conference Panel

6:00 Cocktail Reception, Great Hall

CONFERENCE PANEL

HOWARD A. SCHNEIDERMAN
Senior Vice President
for Research and Development
Monsanto Company (Moderator)

EDWARD E. BARR
Chairman, New Jersey Commission
on Science and Technology
and
President and Chief Executive
Officer, Courtaulds U.S.
Developments Inc.

ORVILLE G. BENTLEY
Assistant Secretary
for Science & Education
U.S. Department of Agriculture

ROBERT H. BURRIS
Professor
Department of Biochemistry
University of Wisconsin

DONALD L. LANGENBERG
Chancellor
University of Illinois at
Chicago

RICHARD R. NELSON
Professor of Economics
Yale University

DISCUSSANTS

DONALD S. BEILMAN
President
Microelectronics Center of
North Carolina

MARVIN C. GUTHRIE
Director
Office of Technology Administration
Massachusetts General Hospital

GORDON HAMMES
Professor of Chemistry
Cornell University

JAMES L. HERBERT
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Deputy Secretary for Technology
& Policy
Ben Franklin Partnership Program
Pennsylvania

HUBERT J.P. SCHOEMAKER
President
Centocor, Inc.

THOMAS STELSON
Vice President for Research
Georgia Institute of Technology

Program Changes

WILLIAM G. ANLYAN, *Chancellor for Health Affairs, Duke University* **will replace DONALD L. LANGENBERG,** *Chancellor, University of Illinois at Chicago*

FRANKLIN A. LINDSAY, *Founder of Engenics and Former President and Chairman, Itek Corporation* **will be unable to participate in Session 2**

APPENDIX C

NEW ALLIANCES AND PARTNERSHIPS IN AMERICAN SCIENCE AND ENGINEERING
December 5, 1985

Conference Participants

Louis Ameen
Science Counselor
Royal Embassy of Sweden

David Anderson
Associate Project Director
Center of Excellence for Computer Applications
University of Tennessee at Chattanooga

William G. Anlyan
Chancellor for Health Affairs
Duke University

Jesse Ausubel
Program Coordinator
National Academy of Engineering

Marietta L. Baba
Assistant Provost
Wayne State University

Albert A. Barber
Vice Chancellor - Research Programs
University of California, Los Angeles

Edward Barr
President and Chief Executive Officer
Courtaulds US Development Inc. and
Chairman, New Jersey Commission on Science & Technology

Gerhard M. Baule
Director of Technology Application
CASE Center
Syracuse University

Donald S. Beilman
President
Microelectronics Center of North Carolina

Alan J. Bennett
Vice President Research
Varian Associates, Inc.

Orville G. Bentley
Assistant Secretary for Science and Education
U.S. Department of Agriculture

James Biggers
Director, NSF/Industry Center for Dielectric Studies
The Pennsylvania State University

Kenneth B. Bischoff
Chairman, Council for Chemical Research, and
Professor, Department of Chemical Engineering
University of Delaware

Justin Bloom
President
Technology International

David Blumenthal
Executive Director, Center for Health Policy and Management
JFK School of Government
Harvard University

Christian C. Bolta
Director, Advanced Technology
Combustion Engineering, Inc.

Elizabeth Briody
General Motors Research

Alfred E. Brown
Consultant

Glenn R. Brown
Senior Vice President Technology
The Standard Oil Company (Ohio)

Jack E. Brown, Jr.
Manager/TIE-IN Administrator
Technology Innovation Division
Ohio Department of Development

Clark W. Bullard
Director, Office of Energy Research
University of Illinois at Urbana-Champaign

April Burke
Director, Clearinghouse University/Industry
American Association of Universities

John J. Burns
Adjunct Professor
Rockefeller University

John Burris
Executive Director
Board on Basic Biology
Commission on Life Sciences
National Research Council

Robert Burris
Professor, Department of Biochemistry
College of Agriculture and Life Sciences
University of Wisconsin-Madison

William Butcher
Director, Special Activities
Directorate for Engineering
National Science Foundation

William T. Butler, M.D.
President
Baylor College of Medicine

John D. Caplan
Executive Director
General Motors Research Labs

Burt Carlson
Senior Staff Associate
Capital Resources Group
Center for Policy Research
National Governors' Association

Marvin Cassman
Senior Policy Analyst
Office of Science and Technology Policy
Executive Office of the President
The White House

James H. Clinton
President
Gulf South Research Institute

Robert L. Clodius
President
National Association of State Universities and Land Grant Colleges

Edward Cohen
Executive Director
New Jersery Commission on Science and Technology

John J. Connolly
President
New York Medical College

Dale R. Corson
Chairman
Government-University-Industry Research Roundtable
National Academy of Sciences
National Academy of Engineering
Institute of Medicine

John P. Crecine
Senior Vice President for Academic Affairs
Carnegie-Mellon University

Robert L. Davis
Dean, School of Engineering
University of Missouri, Rolla

William T. Davis
Director of Licensing
Pfizer, Inc.

John Deardon
Director
University Sponsored Projects Office
The Johns Hopkins University

Dan Dimancescu
Partner
Technology and Strategy Group

Helen Baca Dorsey
Advanced Technology Coordinator
Texas Economic Development Commission
State of Texas

Jack Dustin
Center for Urban Studies
University of Akron

Karen Ekelman
Fellow
National Academy of Engineering

Lois Edwards
Staff Officer
Academy Industry Program
National Academy of Sciences
National Academy of Engineering
Institute of Medicine

Charles (Bud) A. Eldon
President
IEEE

J.D. Eveland
Director
Technology Applications Research
COGNOS Associates

Larry R. Faulkner
Head, Department of Chemistry
University of Illinois at Urbana

Estelle Fishbein
General Counsel
The John Hopkins University

L.S. (Skip) Fletcher
Associate Dean of Engineering, and
Associate Director of the Texas Engineering Experiment Station
Texas A & M University

Harry G. Foden
Vice President
Arthur D. Little, Inc.

R. Scott Fosler
Vice President and Director of Government Studies
Committee on Economic Development

Maritza Marie Friedman
Assistant Director
Office of Economic Development
Montgomery County Government
Montgomery County, Maryland

Richard J. Fruehan
Director, Center for Iron and Steelmaking Research
Department of Metallurgical Engineering and Materials Science
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Osmund T. Fundingsland
Chief Science Advisor
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U.S. General Accounting Office

Antonio Furino
Professor of Economics
University of Texas Health Science Center, and
University of Texas at San Antonio

Ryszard Gajewski
Program Manager, SBIR Program
U.S. Department of Energy

Bruce C. Gates
Professor and Director
Department of Chemical Engineering
University of Delaware

Douglas Getter
Manager, Research & Development Gr
Iowa High Technology Council
Iowa Development Commission
State of Iowa

Joseph Goldstein
Vice President for Research
Lehigh University

David Goldston
Committee on Science and
Technology
U.S. House of Representatives

Serge Gratch
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Sciences Laboratory Research Staff
Ford Motor Company

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The Proctor and Gamble Company

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Marvin Guthrie
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Massachusetts General Hospital

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Executive Director
Committee on Science and
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U.S. House of Representatives

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Associate Administrator
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U.S. Department of Agriculture

Ezra D. Heitowit
Staff Director, Science, Research,
and Technology Subcommittee
Committee on Science and
Technology
U.S. House of Representatives

Austin N. Heller
President
Austin N. Heller, Inc.

James L. Herbert, Jr.
President
Neogen Corporation

John Hile
Director of Sales and
Marketing
Irvine Industrial Research
and Development Company

Christopher T. Hill
Senior Specialist in Science
and Technology Policy
Congressional Research Service
Library of Congress

Allan R. Hoffman
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National Academy of Sciences
National Academy of Engineering
Institute of Medicine

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University of Illinois

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Microelectronics Center
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Professional Staff
American Council on Education

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California Institute of Technology

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Director, National Measurement Laboratory
National Bureau of Standards

Elmima Johnson
Special Assistant
Directorate for Science and Engineering Education
National Science Foundation

Lynn G. Johnson
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University of Akron

Robert M. Jones
E.S.M. Department
Virginia Polytechnic Institute

Angel G. Jordan
Provost
Carnegie-Mellon University

Simon W. Kantor
Research Professor and
Program Director, CUMIRP
Polymer Science & Engineering Department
University of Massachusetts

Anne Keatley
Director, Academy Industry Program
National Academy of Sciences
National Academy of Engineering
Institute of Medicine

Edward T. Kelly
Washington Director
The Small Business High Technology Institute

Jayne Khalifa
Director, Governor's Office of Science and Technology
State of Minnesota

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The ORI Group

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Head, Industrial Support Section
National Science Foundation

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Executive Director, American Society for Engineering Education

Fred C. Leavitt
Director, Government and Science Relations
Dow Chemical Company

John P. Longwell
Edwin R. Gilliland Professor
Department of Chemical Engineering
Massachusetts Institute of Technology

C. Kim McCarthy
Legislative Analyst
National Machine Tool Builders Association

Edgar McCullough
Dean, Faculty of Science
University of Arizona

James E. McEvoy
Executive Director
Council for Chemical Research

Edward MacCordy
Associate Vice Chancellor for Research
Washington University

James T. Magee
President, Electronic Industries Foundation

Jerome T. Mahone
Director, The Incubator Program
Rensselaer Polytechnic Institute

Michael Mastracci
Director, Regional Services Staff
Office of Research Program Management
Environmental Protection Agency

James F. Mathis
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Exxon (retired)

Louis G. Mayfield
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National Science Foundation

Wilbur L. Meier, Jr.
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James D. Meindl
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Stanford University

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Professor, University of Wyoming and
President, Carbon Fuels Technologies

L. William Miles
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University Patents, Inc.

Henry Moncure
Manager, External R&D
E. I. duPont de Nemours & Co., Inc.

Phyllis B. Moses
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Board on Agriculture
National Research Council

Thomas H. Moss
Dean of Graduate Studies and Research
Office of Research Administration
Case Western Reserve University

David C. Mowery
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College of Humanities and Social Sciences
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Dorothy Nelkin
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Cornell University

Richard R. Nelson
Professor of Economics
I.S.P.S.
Yale University

Richard Norelli
Director, Center for Research and Development
State University of New York, Albany

Judith Obermeyer
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Massachusetts Technology Development Corporation

Abbas Ordoobadi
International Economic Counsellor

Graham W.F. Orpwood
Science Advisor
Science Council of Canada

Robert S. Ottinger
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TRW, Inc.

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University of Colorado

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American Physical Society

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Argonne National Laboratory

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President, North Carolina Biotechnology Center

Dana Peck
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Southeastern Universities Research Association

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Commerce, Science, and Transportation Committee
U.S. Senate

Don I. Phillips
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Walter Plosila
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Frank Press
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National Academy of Sciences

Archie W. Prestayko
Vice President, Strategic Planning and Operations
Smith, Kline, and French Laboratories

Donald R. Price
Vice President for Research
University of Florida

Ronald J. Pugmire
Associate Vice President for Research
University of Utah

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Stuart Rosenfeld
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