Industry-University Research Collaborations: Report of a Workshop

Industrial Research Institute,
Government-University-Industry Research Roundtable,
Council on Competitiveness

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The purpose of this report is to encourage dialogue about the nature of collaborative research ventures. The views expressed in this report are those of the workshop participants and do not represent official policy statements of the Industrial Research Institute; the Government-University-Industry Research Roundtable and its sponsoring organizations, the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine; or the Council on Competitiveness.

The Industrial Research Institute

The Industrial Research Institute was founded in 1938 under the auspices of the National Research Council. Its purposes are to promote, through the cooperative efforts of its members, improved, economical, and effective techniques of organization, administration, and operation of industrial research, including means for more effective interaction with other corporate functions; to generate understanding and cooperation between the academic and industrial research communities; to afford a means for industry to cooperate effectively with government in matters related to research; to stimulate and develop an understanding of research as a force in economic, industrial, and social activities; to encourage high standards in the field of industrial research; and to promote communication and interaction with industrial research organizations in other countries. The IRI is an association of some 260 major industrial companies that provides a means for the coordinated study of problems confronting managers of industrial research and development.

The Government-University-Industry Research Roundtable

The Government-University-Industry Research Roundtable is sponsored by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The Research Roundtable was created in 1984 to foster strong American science and engineering through effective working relationships among government, universities, and industry. The Research Roundtable does not make policy recommendations and does not develop advice or recommendations on specific policies or programs within the range of responsibility of participating government officials.

The Council on Competitiveness

The Council on Competitiveness is a nonpartisan, nonprofit forum of chief executives from business, university, and labor working together to set a national action agenda to strengthen U.S. competitiveness. The Council believes that competitiveness is a compelling priority for the country as a whole because it underpins the standard of living of every American as well as U.S. leadership in the international community.

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Introduction

The prevalence and vitality of research partnerships between industrial organizations and universities have increased dramatically over the last two decades. Data from a comprehensive national survey cited by the National Science Foundation reveal that four times as many industry-university research centers—a total of 286—were established in the 1980s than were created in the preceding ten years (see Cohen, Florida, and Goe, 1993; cited in National Science Board, 1996, page 121). One recent report indicates that up to ninety percent of companies with significant biomedical research interests had relationships with academic institutions in 1994 (Blumenthal et al., 1996), while another survey shows that growth companies engaged in cooperative ventures with universities enjoy increased productivity compared to other companies of similar profile (Coopers & Lybrand, 1995).

Collaborative partnerships have become strategic assets for companies that face increasingly rapid technological change, increasingly intense international competition, and diminishing in-house research resources. Such partnerships have become more attractive to universities, too, as overall growth in public funding for research has slowed substantially since the 1980s. In constant dollars, the amount of academic research and development (R&D) financed by industry increased about 265 percent from 1980 to 1993; in fiscal year 1995, industry provided a total of $1.5 billion for R&D spending by universities, or 6.9 percent of the total academic research base (exclusive of Federally-Funded Research and Development Centers; National Science Board, 1996). The federal government's efforts in the 1980s to stimulate technological innovation while reducing spending spawned an array of initiatives designed specifically to encourage industry-university collaboration in R&D. State governments, too, have stepped forward with incentives and programs that build upon their closer ties to the local and regional industrial base (Celeste, 1996).

As the number and durability of joint ventures rises, understanding of the factors that contribute to their success and to the satisfaction of the partners grows (see for example McHenry, 1990; Geisler, Furino, & Kiresuk, 1990, 1991; Chatterji & Manuel, 1993; Bloedon & Stokes, 1994; Cohen, Florida, & Goe, 1994; MacLachlan, 1994; Reid, 1994; Slowinski, Farris, & Jones, 1993; Wolff, 1994; and Giordan, 1995). Many assume that industry looks to academia primarily as fountain of basic, leading-edge research. Entrepreneurial academics, common lore continues, turn to industry for additional funding and for access to state-of-the-art facilities and equipment. However, the empirical literature examining the expectations and satisfaction of university and industry representatives involved in such joint ventures reveals a more heterogeneous and nuanced portfolio of motivations and considerations (Feller and Roessner, 1995).

The most general finding to emerge is the recognition that immediate commercial return is neither the only, nor necessarily the predominant, motivation for companies to enter into research relationships with university scientists. Rather, many industry leaders state they value universities most as wellsprings of scientifically trained personnel (Government-University-Industry Research Roundtable, 1991), and as windows on the future of technology.

In their assessment of industry's interest in university research, Feller and Roessner (1995) assert that at least two sets of factors contribute to continuing uncertainty about the means of predicting or evaluating success in industry-university collaborations. First, the range of models or structures for collaboration is extremely diverse. A corporation may fund a specific project or an individual investigator as a consultant; a consortium of companies may contribute to university-affiliated research or technology centers; or corporate, state, and federally-funded academic investigators may collaborate, either on short-term projects or on long-term programs. As the structures of these partnerships vary, so do the expectations of participants and the criteria by which success can be defined and evaluated. Second, the general use of quantitative indicators of performance and success, such as the number of patents, publications, or new products, fails to capture the diverse benefits from joint research ventures that both corporate and academic participants seek. Indeed, different individuals within different divisions of a company may seek different outcomes, and the objectives of many who participate in collaborative partnerships may change or be redefined over time. Quantifiable metrics for such complex success factors have been difficult to devise.

As the sheer number and complexity of collaborative research partnerships increase—as the growth in federal funding slows or reverses, as large capital costs drive the development of consortia, and as evolving telecommunications technologies eliminate barriers to collaboration by lessening the importance of proximity between partners—members of the Industrial Research Institute (IRI), the Government-University-Industry Research Roundtable (the Research Roundtable), and the Council on Competitiveness (COC) believe it will be ever more important that corporate managers, bench scientists, and decision makers in government, universities, and industry better understand the structure and nature of successful and unsuccessful partnerships.

To make progress toward this goal, the three organizations cosponsored a workshop at Duke University in the late fall of 1995. Participants in the conference included representatives of industry and academia with extensive experience in organizing and managing research collaborations (see roster of attendees in Appendix C). The agenda centered around four case studies of actual industry-university partnerships, and it included breakout sessions designed to facili

tate discussion about the precursors to, and the characteristics of, successful joint ventures. In this report we summarize the case studies as they were presented by those involved directly in these activities, and the content of breakout discussions. Though it does not purport to be comprehensive, we hope that this brief report of experience in the critical area of industry-university partnerships can serve as a road map for others seeking to stimulate and to nurture collaborative research relationships between industrial and academic participants.

Background to Case Presentations

The cosponsors of the workshop solicited proposals from member companies of the IRI that sponsor research at universities, to present as cases studies. Four proposals were selected to represent a diverse group of partnerships.

SINGLE COMPANY/MULTI-UNIVERSITY MODEL

Hoechst-Celanese-Rutgers University-North Carolina State University-University of North Carolina Chapel Hill: Targeted partnerships were established as an experiment to determine if the company could conduct a significant portion of its discovery research externally, and whether this process would be beneficial to the partner universities.

MULTI-COMPANY/SINGLE UNIVERSITY MODEL

Massachusetts Institute of Technology Media Laboratory: This laboratory includes research that extends into a broad range of new information technologies. It attracts a high proportion of corporate funding relative to many university laboratories. Corporations (including Philips, Hewlett-Packard, Digital Equipment, Hearst, Pulitzer Publishing, and others) support and participate in the Laboratory's programs through a variety of sponsorship agreements.

SINGLE COMPANY/SINGLE UNIVERSITY/STATE SUPPORT MODEL

Cabot Corporation-Pennsylvania State University-Pennsylvania-Ben Franklin Partnership: This joint industry/university/state project has played a major role in Cabot's significant progress toward becoming a supplier of fine particle barium titanate.

MULTI-COMPANY/MULTI-UNIVERSITY MODEL

University of Rochester Center for Electronic Imaging Systems: The central thrust of research at the Center, which is based at the University of Rochester and includes the participation of scientists from the Rochester Institute of Technology, is "imaging in the information age." The long-term vision of its founders is to develop a leading national center for all phases of electronic imaging systems. The Center serves a diverse customer base that includes its corporate sponsors, the University of Rochester

and Rochester Institute of Technology, and the State of New York.

During the workshop, case presentations were made by representatives of the partnering organizations, each of whom were asked to address the following, standard set of questions:

Why Partner?

What were each partner's motivations in entering into the partnership? What were the expected outcomes? What were the primary concerns in arranging the partnership? What were the major impediments to establishing the partnership and to implementing it? What has been the most surprising aspect of the partnership as it has evolved?

What Kind of Research is Being Performed?

What is the relative amount of applied and basic research attempted or accomplished by the partnership? How does this research differ from that conducted by individual investigators under government sponsorship? Industrial researchers often express concern that the nation's basic research capacity is being eroded; does this industry-sponsored research correct or exacerbate that trend? How do partnerships that originate with industry differ from those whose impetus comes from universities seeking matching support from industry for government grants?

How Do Partnerships Actually Function?

How is the success of the partnership evaluated? What measures are in place to ensure adequate transfer of knowledge among the parties to the partnership? Describe the processes for both critical decision making and conflict resolution that have been established for the partnership. How important is physical proximity, or actual presence on campus, to the success of this venture? How important is the exchange of personnel between members of the university and of the industry lab? How has such exchange been accomplished?

How Do the Partnerships Affect Education?

What roles do graduate students play in the collaboration? How have concerns about graduate students—including project continuity, confidentiality, the students' need to publish—affected the structure of the partnership? Can partnerships lead to broader changes in the curriculum and educational approach universities take toward undergraduate and graduate education?

Summary of Case Presentations

CASE STUDY I: HOECHST-CELANESE-RUTGERS UNIVERSITY-NORTH CAROLINA STATE UNIVERSITY-UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL

Hoechst-Celanese Corporation entered into partnerships with Rutgers, the University of North Carolina, and North Carolina State University in 1991, after company and university officials found that they had a mutual interest in conducting basic, discovery research in such areas as neuroscience, animal health, polymers, and technology management. The objective of the partnerships is to foster an environment conducive to moving forward aggressively, rather than incrementally, in areas of basic research relevant to the company's core business. Hoechst-Celanese started with an investment of $1 million at each of the partner schools in order to gain strategic access to a knowledge base in leading-edge science that could not be developed and maintained internally. Hoechst-Celanese also seeks to generate concepts that can be transformed into commercially viable products or processes, to set up flexible mechanisms to explore a wide range of interests while leveraging risk, and to subject its research to independent evaluation by a third party. Each of these objectives is served by partnering with academic investigators. Most importantly, Hoechst-Celanese wants to build a comprehensive system of interaction with the partner schools that will enable it to find new business and technology ideas that are not obvious in isolation, but rather depend on the synergy of partners and their varied perspectives. In choosing partners, Hoechst-Celanese considered such factors as proximity and its ability to form a relationship with university researchers.

Of course, working arrangements with Hoechst-Celanese promise specific benefits to the participating universities, too. Those benefits include a research thrust that focuses on productive and applied outcomes, increased financial and educational resources, and a real-world perspective on the imminent job market of the 21st century. The company and its partner schools both benefit from the program's ability to generate interdisciplinary interactions among different university departments. Often, the external catalyst provided by a corporate sponsor can foster bridging between academic departments that typically vie for resources.

Three levels of interaction characterize these partnerships between Hoechst-Celanese and its academic affiliates. The first strategic set of interactions occurs at the executive level, as key officials at the universities and the company meet to gain understanding of one another's intent, capabilities, and structure. The second level of interaction is exploratory; project managers

from Hoechst-Celanese meet with university department heads and senior investigators to identify common research interests. These interactions are instrumental in utilizing broad university resources to discover unforeseen opportunities. The third set of interactions occurs at the program level, when company and university researcher teams carry out a defined piece of research. To facilitate program-level interactions, the company has established networking groups at the partnership schools so that company and university researchers can provide continuous feedback to one another. Members of the partnerships assert that each of these three levels of interaction adds value to the partnership and facilitates creative synergy. Together, they constitute a flexible management structure that allows the parties to meet emerging needs.

The partnership infrastructure includes an allocation process by which a joint committee identifies pertinent areas of research interest, requests proposals from faculty, and selects proposals to fund. Company grants support workshops, educational programs, research contracts, and consulting arrangements. To foster an atmosphere of mutual trust, the parties agree to deal with intellectual property rights in a blanket agreement under which deliverables developed within the partnership belong to the university, and the company has the right of first refusal to commercialize those products. In this way, university researchers and company scientists can disseminate research results without compromising valuable patent rights.

CASE STUDY II: THE MIT MEDIA LABORATORY

The MIT Media Laboratory (the Lab) was created in 1985 to perform exploratory, pre-competitive research in new information technologies arising from the merging of the broadcast, publishing, and computer industries. The Lab focuses on leading-edge concepts such as advanced digital television, holographic imaging, computer music, electronic publishing, artificial intelligence, autonomous agents, and the human/machine interface. The Lab conducts a broad range of interdisciplinary research with the support of approximately 125 sponsors. About 60 percent of these sponsors participate in one of three multi-sponsor consortia: News in the Future; Television of Tomorrow; and Things That Think.

The Lab operates on a budget of approximately $23 million per year. In 1994-95, approximately 85 percent of its contract research funding was provided by more than 100 corporate sponsors worldwide, representing industries ranging from telecommunications to finance. The balance of funding primarily came from various federal agencies. Several sponsorship vehicles sustain the Lab's operating budget, including endowment funding, contract research, major equipment donations, and consortia.

Corporate sponsors of the Lab initially entered into these partnerships with hopes the venture would yield benefits traditionally

associated with industry-university collaborations, as well as benefits unique to the Lab's particular management, structure, and programs. Traditional benefits include the exchange of financial support for access to the cutting-edge research normally associated with leading universities, and to the strategic vision of scholars. Such access supports corporate recruiting efforts and leads to consulting arrangements with key faculty in areas critical to industrial research. In the immediate case, some corporate sponsors have been motivated in part by the personal charisma and strategic vision of the Lab's director, and to other scholars drawn to this creative environment.

Interactions between the Lab's staff and the sponsor's personnel occur both through formal meetings and via informal exchanges of information. The Lab is an open intellectual environment that encourages the sharing of discoveries and the practical application of inventions; it allows all major sponsors the opportunity to share in all of the intellectual property it generates under terms that are based on the scale and nature of their support, ranging from royalty-free, non-exclusive world-wide licenses, to royalty-bearing licenses with negotiable terms. The Lab's programs in media arts and sciences attract students from a variety of backgrounds in technical fields and the arts.

Corporate sponsors note that research programs benefit from their partnerships with the Lab: they testify that the Lab's activities are highly relevant to their core businesses; that the Lab's leadership is creative and influential in the technical community and with policy-making government agencies; that interactions with the Lab's researchers are intellectually stimulating to their staffs; and that the Lab is very effective in providing a forum for industrial and academic research leadership to meet to discuss long-range trends and to focus on critical issues.

Recent economic pressures that have had an impact on the resources of most industrial research organizations also have affected industry-university partnerships like this one. With smaller research staffs and reduced capital equipment budgets, the corporate research laboratories affiliated with MIT hope to compensate for diminishing resources by contracting with the university for projects having shorter-term, specific goals, and by making use of special facilities. Unable to maintain active programs in all technical fields important to their businesses, they also view the Lab and other university partners as potential sites for shared, pre-competitive research.

At the same time, recent economic pressures on industrial research have led to higher expectations both from their staffs and from university partnerships. The Lab's corporate sponsors note lower than expected transfer of industrially-applicable knowledge from the Lab and fewer than expected opportunities to acquire intellectual property relevant to their businesses. The Lab's management, in turn, cautions that some companies may not be taking full advantage of the opportunities available.

CASE STUDY III: CABOT CORPORATION-PENNSYLVANIA STATE UNIVERSITY-PENNSYLVANIA-BEN FRANKLIN PARTNERSHIP

The partnership between Cabot Corporation, Pennsylvania State University (Penn State), and the Commonwealth of Pennsylvania's Ben Franklin Program was formed in 1991 to develop an enabling technology for production of fine particle barium titanate powders used in the production of electronic components. Unique low-fire properties of these compounds were discovered during the course of unsponsored research at Penn State. The company needed to carry out further R&D activity in order to find a way to add fluxes that would enhance the product's performance in such applications as thick film capacitor inks, multichip modules, and multilayer capacitors.

Cabot sees the partnership as a way to develop a line of differentiated products at relatively low costs, thereby enhancing the company's business opportunities and expanding one of its divisions. The partnership also represents a means of sharing the risks of new technology development, of utilizing external resources in a cost-effective manner, and of gaining additional market awareness of emerging technologies. In addition to these generic expectations, Cabot seeks to take advantage of Penn State's strong reputation in the field of electronic ceramics. For Penn State, the partnership presents a source of research funds and support for graduate student research, and an opportunity to learn about industry's needs and about intellectual property issues. For the state of Pennsylvania, benefits include job creation, increased revenues, and economic development.

Cabot Corporation runs the program as a small business operating with limited resources. The company makes decisions concerning strategic selection and use of critical resources. Its contribution to the partnership includes project direction, funding, and in-kind research services. The actual research is carried out in Penn State's Center for Dielectric Studies, which has a strong reputation in the field of electronic ceramics. In addition to scientific expertise, Penn State also provides specialized equipment as well as market information and contacts. The State of Pennsylvania, through the Ben Franklin Program, provided the matching funds that ultimately persuaded Cabot to go ahead with the project.

The program's focus on deliverables, and on frequent and strong personal interaction between the participants, are fundamental to the perceived success of the partnership and to the satisfaction of those involved. The parties devise a project plan that assigns specific tasks and sets forth milestones and timetables. Graduate students serve as the primary researchers on the university side and they are involved in all levels of communication between partner organizations. In terms of effects on education, the partnership process enhances the competence

of university researchers for collaborating with private partners as they learn what is important to industry, including intellectual property, confidentiality of proprietary information, responsiveness, timing, accountability, and presentation skills.

CASE STUDY IV: UNIVERSITY OF ROCHESTER CENTER FOR ELECTRONIC IMAGING SYSTEMS

The central thrust of the University of Rochester's Electronic Imaging Center (the Center) is toward imaging in the information age. The Center, founded in 1992, is part of the National Science Foundation's Cooperative Research Centers Program. The long-term vision of its founders is to develop a leading national center for all phases of electronic imaging systems. The research performed at this center consists mainly of fundamental, discovery research in electronic imaging. For the industrial partners, which include Eastman Kodak, Xerox, and 3M, incentives for entering into partnership agreements with the Center include strategic access to an incubator of pre-competitive technologies. Participation also enables diffusion of new ideas into these companies, enhances corporate R&D efficiency, invigorates corporate research staffs, and provides assistance to small companies.

Governance of the Center includes five entities: the Center's management team; a Policy Committee from the University; the Industrial Advisory Board*; the National Science Foundation; and the New York State Science and Technology Foundation. The Center has four major divisions: research, technology, business innovation, and community outreach. The business innovation team carries out marketing research studies for proposed new products, finds new market niches for existing technologies, and identifies prospective commercial markets for military technologies. The community outreach group focuses on facilitating interactions in the field through conferences, symposia, and other educational activities.

A strategic plan for the Center's work is developed in conjunction with the Industrial Advisory Board. Areas of research emphasis are selected by the faculty after discussions with representatives from the Center's corporate sponsors, and related plans remain valid for five years, during which time they are revised in accordance with emerging technological trends. Currently, the research portfolio includes nine primary themes: electronic imaging systems; digital video; image quality; image processing; color; imaging through turbulence; automatic object recognition; visualization and display; and optomechatronics.

* An Industrial Advisory Board, or IAB, is mandated by the NSF for each NSF-supported center; IABs include one designated representative from each participating company.

Once a research strategy and areas of emphasis are identified, the research is implemented through teams of triplets, consisting of a faculty investigator, a graduate student or post-doctoral fellow, and an industrial researcher. The purpose of the triplet model is to reduce time to market: partners agree that this system gives the faculty member autonomy and responsibility for technology transfer; encourages the student or post-doctoral student to stimulate interaction between faculty and industry representatives; and recognizes the industry partner as the primary evaluator of progress and success.

Broadly construed, the Center's strategy revolves around three goals: to contribute to economic development of the region; to carry out relevant fundamental research; and to enhance the educational missions of the University. The Center's benefits to education include: enhancing the university's ability to attract and to educate high-quality students; demonstrating an orientation toward problems relevant to industry; offering faculty and students the advantage of interacting with industry; and continuing education for scientists in imaging science.

Break-Out Groups: Objectives

Following case presentations, workshop participants broke into smaller groups to address several questions concerning the factors that define successful partnerships. These included:

- What are the general characteristics of successful partnerships? What quantitative and qualitative measures can be employed to evaluate success?
- What are the criteria for success in these endeavors?
- What specific actions should each of the research sectors and the participating or sponsoring organizations take to improve current and future collaborations?

The final session of the workshop included reports on these breakout discussions.

CHARACTERISTICS AND MEASURES OF SUCCESSFUL PARTNERSHIPS

Discussions during breakout sessions identified a host of characteristics or indicators of successful research partnerships. The critical characteristics differed for the various parties to the collaboration.

For Industry

Characteristics of success identified by industrial participants included:

- increased awareness of and exposure to new technologies;
- increased opportunities to enhance the knowledge base of employees;
- greater opportunity to contribute toward the conception of new strategies;
- greater access to a highly trained pool of potential personnel;
- greater access to intellectual property, patents, and publications; and
- enhanced stature in academia and industry, leading—among other things—to recruitment of knowledgeable employees.

For Universities

The success of a collaborative arrangement for academic parties to such partnerships is evidenced in:

- sustained corporate support of research;
- enhanced appreciation of industry's needs with respect to economics, marketing, environment, and risk;
- expanded research and learning opportunities for graduate students;
- increased publications and patents; and

- opportunities to consult outside of academe.

For State Government Research Centers

State and local governments acknowledge the success of industry-university collaborations when they contribute to:

- the generation of jobs;
- the formation of spin-off companies;
- an increased tax base; and
- overall economic development.

For All Participants

Certain indicators of success are common to all parties to collaborative research relationships. For industry, university, and government participants alike, successful partnerships deliver value for each partner that is greater than any participant would enjoy alone. Among the many approaches to demonstrating this outcome, discussions during breakout sessions identified the following:

- project milestones are achieved;
- frequent communication between partners occurs;
- the number of quality publications and student theses resulting from collaborative research is comparable to other productive research areas;
- the number and quality of ideas resulting in follow-up activity shows a mutually stimulating influence among the partners;
- intellectual property (e.g., number of patents or copyrights applied for or granted) is generated;
- the number and quality of graduate students or post-doctoral fellows hired by industrial partners are increased;
- continuity of the relationship extends beyond the initial projects; and
- the fiscal status of the partnering company improves.

CRITERIA OR PREDICTORS OF SUCCESS

Participants identified a host of prerequisites or criteria they believe predict success in research partnerships. These factors have been grouped into three general categories: (1) "attitudinal" issues, or specific aspects of the cultures and objectives of partner organizations; (2) "systems" factors, or aspects of organizational process and infrastructure; and (3) management issues.

Cultural and Attitudinal Factors

Certain attitudes and expectations presage successful partnerships. These include:

- a clear understanding at the outset of partners' roles and the rules of engagement;
- mutual perception of value in each partner's contribution to the relationship;

- mutual respect and appreciation of organizational differences, missions, motivations, and working environments;
- a shared agenda and desire to work together;
- the ability of all partners to interact with one another on an interdisciplinary basis, and to see beyond the bounds of individual specialties;
- expectations of and efforts to foster a win-win outcome by all parties to partnership negotiations; and
- minimal impact of the "not-invented-here" syndrome on the part of industry, and of a traditional academic tendency to look with less regard upon applied or problem-solving research, i.e., an attitude of ownership and responsiveness on all sides.

Systems Factors

Certain facets of organizational process and infrastructure enhance partnership efforts. These include:

- intellectual property and publication policies that balance industry's need to secure patent protection with the university's obligation to disseminate knowledge freely;
- agreements that are tailored to the size of the project, to the needs of the parties, and to other factors specific to the project; and
- incentive systems on both sides of a partnership—and especially within the university's tenure and promotion system—that reward interdisciplinary collaborations.

Management Issues

Senior management in industry and in universities have a tremendous impact on the probability of success in industry-university collaborations. Several requirements for success are identified below.

- Champions are needed who have a vested interest in the partnership's success and who can match industry and university scientists.
- Senior management or executive level personnel must demonstrate support for partnering by providing adequate financial, human, and capital resources. Industry must be willing to assign their best and brightest technicians to collaborative ventures.
- An infrastructure must be in place to execute, manage, evaluate, and reward collaborations.
- The industrial management structure should empower front-line researchers as decision makers for the projects.
- Frequent and clear communication is needed on expectations and progress at all levels of the partnership.

Finally, participants agreed that successful partnerships typically are market-driven, not technology-driven. They concurred, too, that the most successful partnerships include a system of mutually defined metrics to measure success and satisfaction, and to

foster continuous improvement in the processing, functioning, and effectiveness of the partnership.

APPROACHES TO IMPROVING INDUSTRY-UNIVERSITY PARTNERSHIPS IN THE U.S.

Finally, workshop participants suggested productive approaches to increasing the number, value, and effectiveness of industry-university research partnerships. Some of the many ideas to emerge are listed here.

For Industry

Options for industry activity include these:

- take the lead to develop technology goals and development strategies with the participation of universities, state, and federal agencies;
- designate contact points for universities as liaisons to establish continuity in communications and linkages;
- communicate to students and to faculty the reality of business priorities and expectations for newly-hired scientists and engineers.

For Universities

Members of the academic community together might:

- become more user-friendly by designing intellectual property policies that facilitate commercialization, by providing one-stop shopping, by offering databases, and by developing marketing interfaces with industry;
- facilitate sabbaticals at companies for interested faculty, and arrange cooperative opportunities for students;
- modify incentive and reward systems to award credit for interdisciplinary, industry-university research collaborations, thereby acknowledging the value of team approaches and of applied research.

For Research Partners

All participants in collaborative research can strive to:

- reach a clear understanding about the different motivations for participating in collaborative research in order to foster a win-win climate for negotiations;
- look for innovative approaches to access research equipment and facilities, e.g. leasing equipment and space, sharing facilities, and using those resources for dual purposes, such as research and testing;
- encourage students to pursue both discovery and problem-solving research;
- encourage strategic relationships between specific universities, specific companies, state agencies, and federal agencies, to broaden interaction beyond technology areas (e.g., business, law, and social sciences);

- publicize and document, on a worldwide basis, success stories, lessons learned, and benchmarks established at conferences, in journals, and elsewhere, to provide guidance to others inclined to experiment with partnerships;
- participate in outreach activities designed to educate elected representatives, as well as the public at large, about the importance of such collaborations to the competitiveness of American business and to economic development within participating states in order to improve the general climate for collaboration.

Finally, national organizations such as the IRI, the Research Roundtable, and the COC, can undertake activities designed to encourage greater collaboration among universities and private companies, and to enhance understanding by representatives of both sectors of their common interests. One example of such activity might entail follow-up workshops to address unresolved issues, including issues of intellectual property.

CONCLUDING DISCUSSION

At present, many disparate forces have coalesced to affect change in the U.S. R&D enterprise. Among the most salient influences on the system are:

- the unprecedented mobility of capital, technology, and human resources, which together have helped other nations develop their own R&D capabilities;
- the rapid ascent of the computer, and information and communication technology, which have spawned entirely new industries;
- the emergence of civilian and commercial interests as primary drivers of leading-edge technology, which now supplement the creative force of the defense sector;
- the accelerated pace and increasing complexity of science and technology, which have given rise to new disciplines and transformed the innovation process itself; and
- the mission to balance the federal budget.

Together, these forces have overtaken the post-1945 system of innovation that developed and sustained U.S. technological preeminence. In the course of this transformation, the roles of universities, industry, and government in the R&D enterprise are changing. A new paradigm of R&D partnerships is emerging, based on the collaboration, rather than the independence, of these key performers.

The emerging trend toward partnerships for research is the central finding of a report recently released by the COC entitled "Endless Frontier, Limited Resources" (Council on Competitiveness, 1996). That report shows that instead of separate islands doing R&D, partnerships will be the way of the

future. While the perspectives and approaches of partners will remain unique, the integrated selection and exploration of key topics and the collective use of complementary strengths will be of vital importance in meeting the challenges of continuing competitiveness that face this nation.

The COC defines partnerships broadly as cooperative arrangements that engage companies, universities, and government agencies and laboratories in varying combination to pool resources in pursuit of shared research objectives. The common thread running throughout all partnerships is the joint commitment of participants to share costs, resources, and experiences in order to draw strength from each other by leveraging capabilities.

The present report on the Duke workshop adds to our knowledge of what successful industry-university partnerships, in their extreme diversity, have in common, and it serves as a template for formulating individual partnerships and a collaborative R&D enterprise. As we go forward, those who will shape the future of R&D must recognize the importance of experiments in partnering, communicating their experiences of failure as well as of success.

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Appendix A

Acknowledgment

This report represents the collective work of all participants at the workshop, and special thanks are given to the case presenters, keynote speakers, breakout-group facilitators, and reporters. The workshop and final report were organized by a steering committee, whose members are listed here:

Pete Bingham - President, Philips Research
Jean Bonney - Director, External Research Program, Digital Equipment
Bob Burkart - Director, Professional Development Services, IRI
Alex Daniels - Consultant to the President, Philips Research
Chad Evans - Council Associate, COC
Mel Lieberman - Professor of Physiology, Duke University
Marc Plotkin - Project Assistant, George Mason University
Allison Rosenberg - Associate Executive Director, The Research Roundtable
Beth Starbuck - Associate Director, Technology Transfer, University of Minnesota

Appendix B

Workshop Agenda

INDUSTRY-UNIVERSITY RESEARCH COLLABORATIONS: OPPORTUNITIES, EXPECTATIONS, AND IMPEDIMENTS

November 28-30, 1995
Duke University
Durham, North Carolina

Industrial Research Institute and the Government-University-Industry Research Roundtable and the Council on Competitiveness

The number of research partnerships between universities and companies is increasing rapidly in response to the growth of knowledge, our quickly evolving marketplaces, and the limited growth in funding. Yet, partnerships remain experiments and are raising many practical as well as policy-related questions.

> **Forty-one percent of the Nation's fastest growing companies have partnerships with colleges and universities —and boast productivity rates 59 percent *higher* than their peers without such relationships. However, of those companies that use college and university resources, about half say barriers limit their partnership's effectiveness . . .**
> *Source: Coopers & Lybrand (1995)*

This workshop agenda will concentrate both on the important and urgent needs of companies and universities resulting from recent and increasing economic pressures, and on those collaborative approaches that can attain the objectives of both entities.

WORKSHOP SCHEDULE

TUESDAY, NOVEMBER 28, 1995		
5:00 pm	Networking Reception	Center Room
5:55	Introductory Statements	
	Jean Bonney, Director, External Research Program, Digital Equipment	
	Welcoming Address	
	Charles E. Putman, Sr. Vice President of Research Administration, Duke University	
	Keynote Addresses	
	Ralph Snyderman, Chancellor of Health Affairs, Duke University Medical Center	
	University-Industry Partnerships in Biomedical Research & Development	
	C. William Gear, President, NEC Research Institute, Inc.	
	Academic and Industrial Research: Can we find a common path?	
7:30	Buffet Dinner	Center Room
WEDNESDAY, NOVEMBER 29, 1995		
7:15 am	Continental Breakfast	Ambassador Allen
7:55	***General Session*** - Welcome from Moderator Charles Hamner, President, North Carolina Biotechnology Center	
8:05	***Case Presentation*** - Hoechst-Celanese-Rutgers University-North Carolina State University-University of North Carolina, Chapel Hill	
9:15	Break	
9:30	***Case Presentation*** **-** Massachusetts Institute of Technology Media Laboratory	
10:45	***Case Presentation*** **-** Cabot Corporation-Pennsylvania State University-Pennsylvania-Ben Franklin Partnership	

Noon	Group Lunch and Speaker	Center Room
	Richard L. Thornburgh, former Governor of Pennsylvania	
	Partnerships in Science & Technology: New Paths to Prosperity	
1:25 pm	General Session	Ambassador Allen
	Case Presentation - University of Rochester Center for Electronic Imaging Systems	
2:45	Break	
3:00	***Break-Out Sessions*** **-** (see lists for each breakout group and room)	As Posted
6:30	Reception/Dinner and Speaker	Center Room
	Denis Gray, Associate Professor of Psychology, North Carolina State University	
	Peter Marinos, Duke University	
	NSF-sponsored Cooperative Research Centers: a successful model	
THURSDAY, NOVEMBER 30, 1995		
7:15 am	Breakfast	Center Room
7:55	***Break-Out Sessions*** **-** (see lists for each breakout group and room)	As Posted
10:00	Break	
10:15	Break-Out Reports	Center Room
11:30	***Wrap-up Report*** - J. Peter Bingham, President, Philips Laboratories	
12:30 pm	Adjourn	

Appendix C

List of Participants

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